Fermi National Accelerator Laboratory

FERMILAB-TM-1873

Final Results from the SDC Dopant Search for New Green Wavelength Shifting (WLS) Fibers VOLUME I

A. Pla-Dalmau, G.W. Foster and G. Zhang

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TABLE OF CONTENTS

Introduction

A scintillating tile/fiber design had been selected for the SDC calorimeter. It consisted of scintillator plates embedded with a wavelength shifting (WLS) fiber which was spliced to a clear fiber. Based on the results from previous radiation damage studies on different scintillating materials, SCSN38 had been chosen for the scintillating tile and BCF91 or Y7 for the WLS fiber. SCSN38 is a blue-emitting scintillator and both WLS fibers use K-27, a green-emitting compound, as dopant.

K-27 has a decay time of approximately 12 ns which is long in comparison to that of most blue-emitting materials. Of all the factors that affect the speed of the scintillator tile/fiber calorimeter, the lifetime of the green-emitting dopant is the dominant component. To increase the speed of the calorimeter, it would be desirable that the green WLS fibers utilized had lifetimes between 3 and 5 ns. However, currently available green WLS fibers exhibit decay times between 7 and 12 ns. Development of new green-emitting WLS fibers with short decay times must be investigated.

The goal of this project was to search for commercially available fluorescent compounds with λ_{abs}=400–450 nm, λ_{em}=450–550 nm, τ=3–7 ns, and quantum efficiency of minimum 0.7 (current K-27 baseline). Large Stokes shift and low self-absorption were not important requirements since the optical pathlength for the shifted light was small. Characterization of the spectroscopic properties of these compounds after styrene polymerization is important since this is an essential part of the manufacturing of WLS fibers.

Organic compounds fluorescing in the region of interest were purchased from Aldrich, Exciton, Lambda Physics, and Eastman Kodak. Polystyrene samples doped with these compounds were prepared in the chemistry laboratory of the Particle Detector Group. The samples had a dopant concentration of 0.02% by weight, with the exception of some dopants which presented solubility problems. In such cases, 0.01% (by weight) solutions were prepared. When the dopants were insoluble even at low concentrations, a crown-ether (C-E) was used as a solubilizing agent. Bulk polymerization of doped styrene solutions was carried out in Pyrex test tubes immersed in a silicone oil bath. After polymerization, the plastic rods were cut into 1-cm thick disks and polished. These disks were then used in all the measurements performed. Transmittance and fluorescence measurements were recorded by the Particle

Detector Group. Light yield and lifetime determinations were performed by SDC members using their setup at Laboratory 5.

Transmittance and fluorescence spectra were recorded with a Hewlett-Packard model 8451A diode array spectrophotometer. All transmittance measurements used undoped polystyrene as the reference. The fluorescence spectra were measured using an external Hg lamp whose light was brought into the spectrophotometer by means of a quartz fiber. Different excitation wavelengths were selected with the use of bandpass filters. Both back-surface (BS) and front-surface (FS) excitation measurements were performed. In the former, light from the quartz fiber excited the sample surface that faced away from the spectrophotometer collection optics. The sample fluorescence was thus viewed through the sample. In the front-surface (FS) excitation measurements, the quartz fiber was positioned so that the UV light excited the sample surface facing the spectrophotometer optics. In this case, the fluorescence was viewed directly and not through the sample. In both geometries, a 45° angle of incidence with respect to the surface plane was used.

For general characterization of the dopants, fluorescence data were recorded using a 313-nm excitation wavelength which is a region where most organic materials absorb and is commonly used in plastic scintillator studies. Nonetheless, the most representative fluorescence measurement is that using an excitation wavelength approximately at 430 nm since it is the wavelength closest to the actual emission of the blue tiles. Some samples would not absorb at such long wavelengths and 360 nm was selected. Other excitation wavelengths used were 400 and 450 nm.

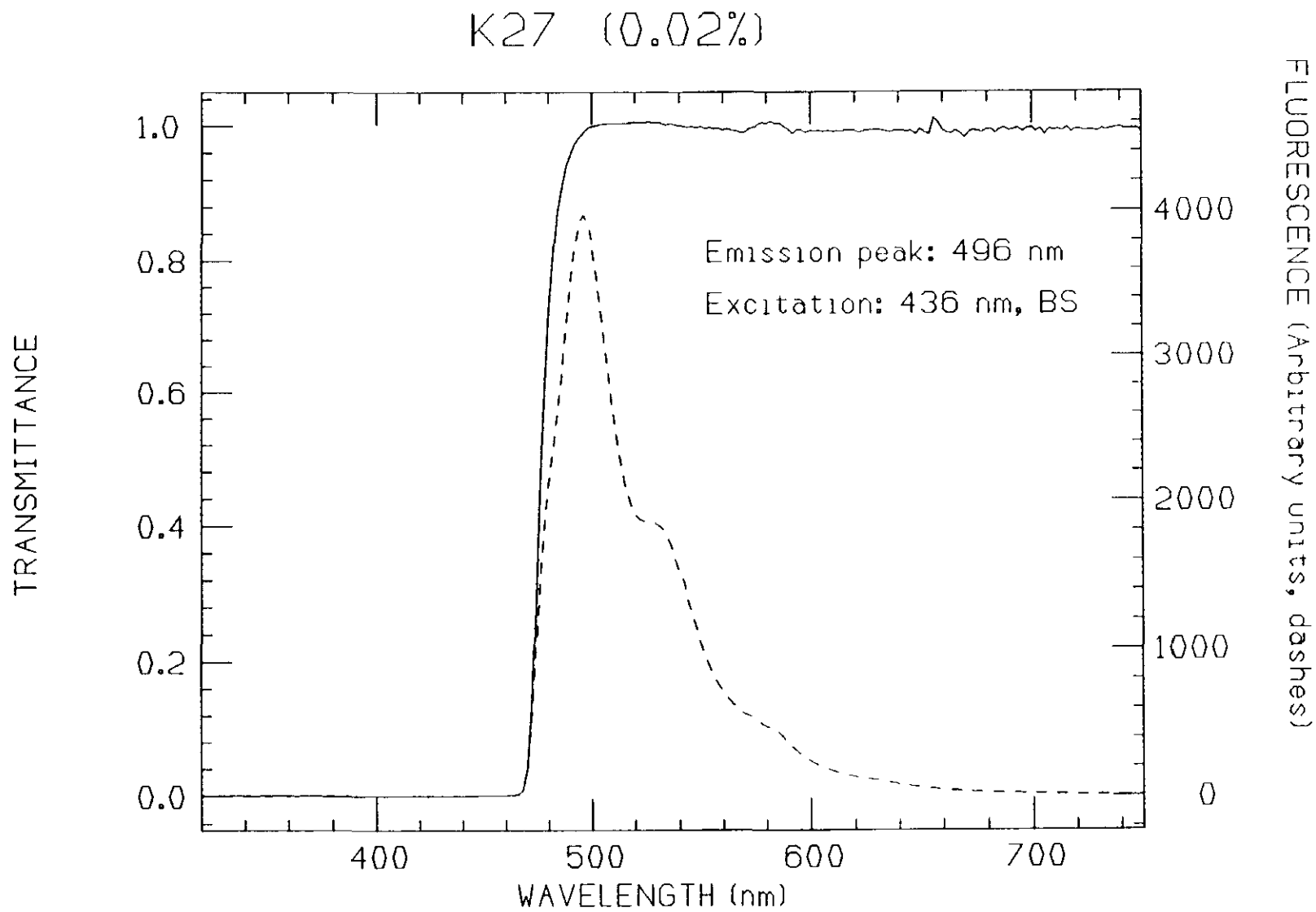
Radiation damage studies were also performed on these samples after the characterization studies were finished. For our convenience, the samples were irradiated in two sets; radiation damage set numbers 20 and 22. Changes in transmittance and light yield were recorded at different stages of the study.

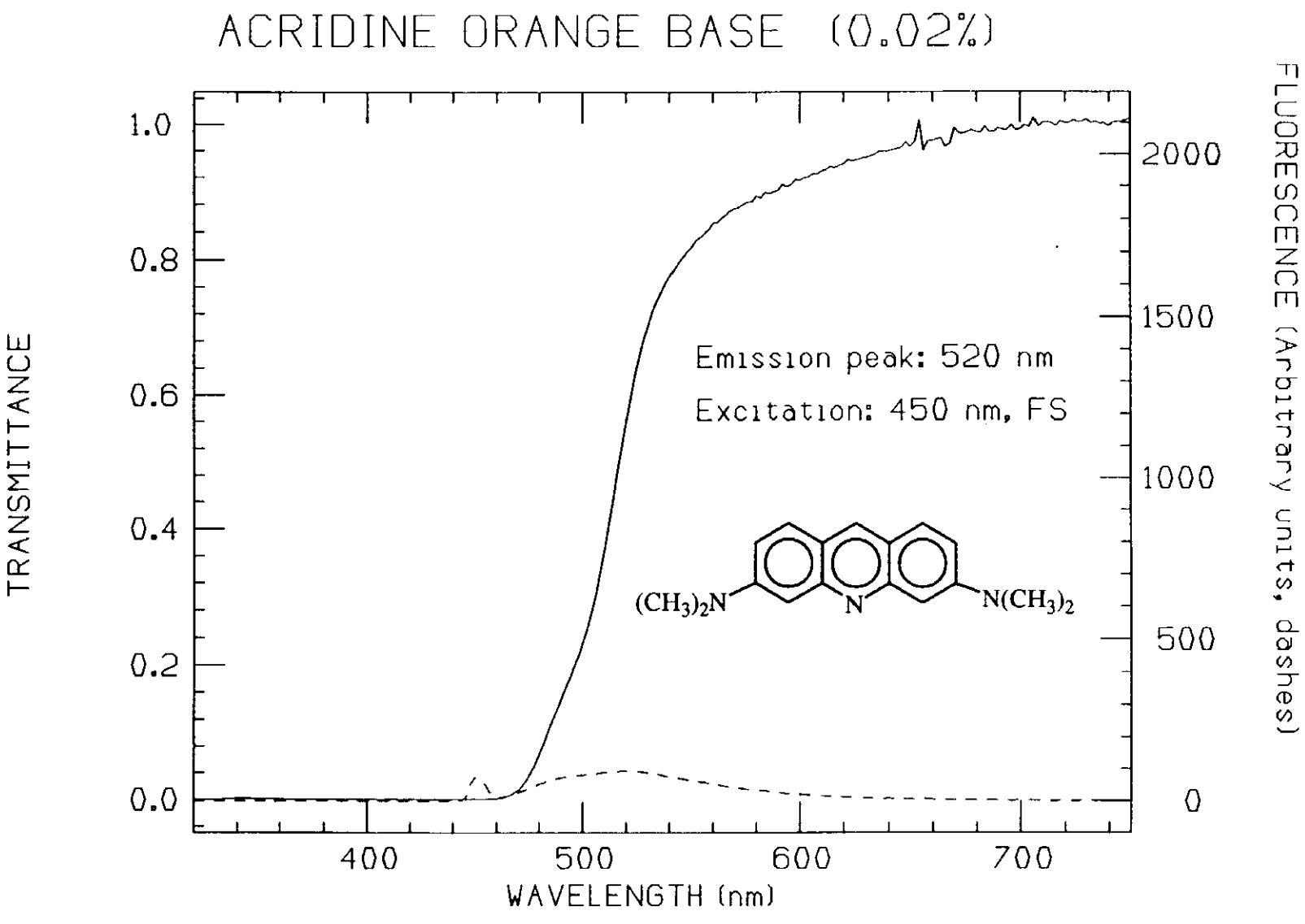
This summary presents the transmittance and fluorescence data for each dopant tested. However, many fluorescence measurements using different excitation wavelengths and orientations were recorded. These data have been compiled in the current two volumes. Volume I presents a plot for each dopant combining transmittance and the most representative fluorescence measurement. Volume II contains the remaining fluorescence plots which can be used as support data.

There are three appendices at the end of Volume I. Appendix A lists the

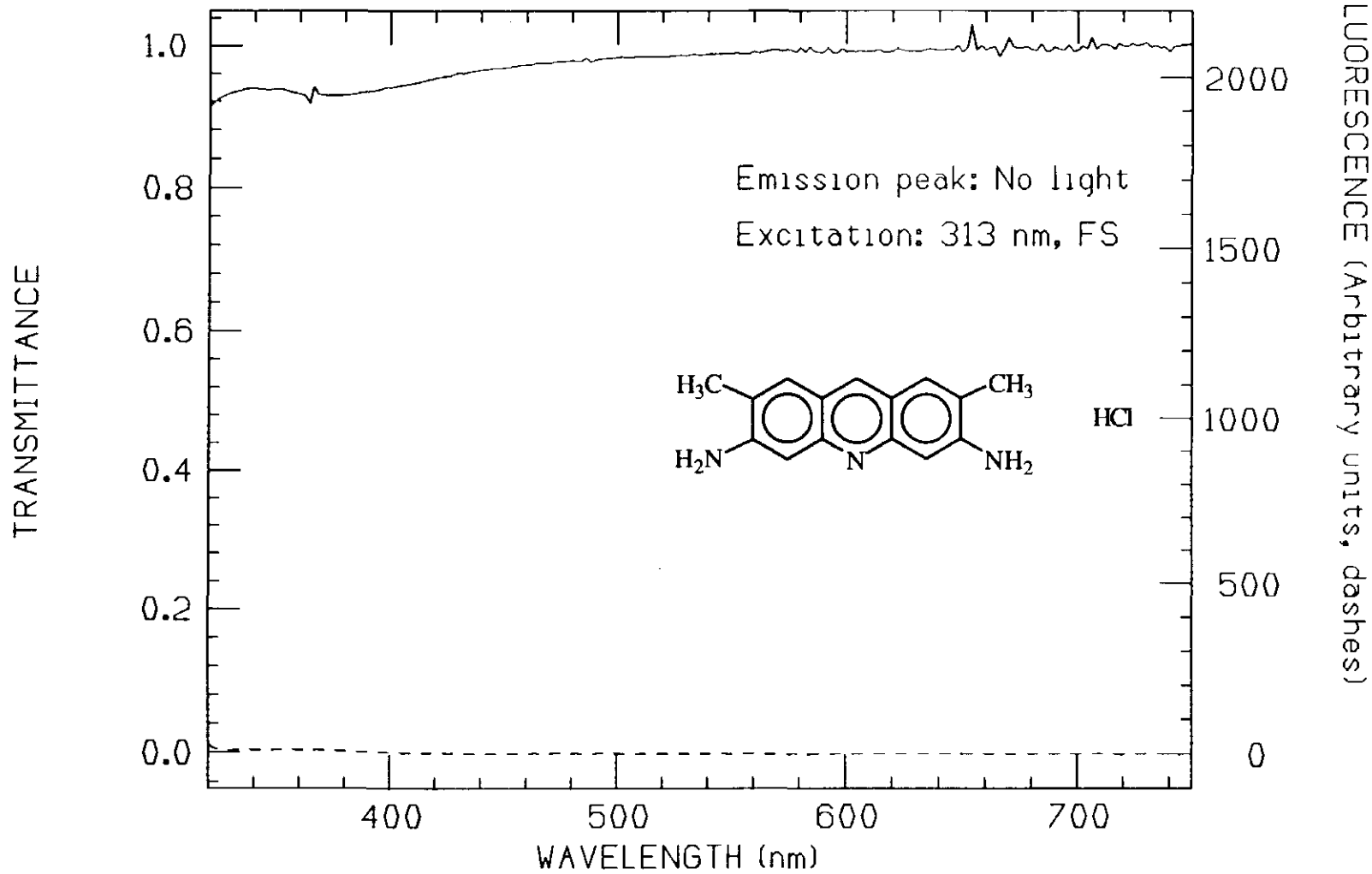
full names and the Chemical Abstracts Service (CAS) registry numbers for all the dopants tested. The CAS numbers are often listed in catalogs and handbooks next to the commercial name of the substance. Usually Material Safety Data Sheets provided by the vendors also contain some of this basic information. The chemical structures were drawn or searched once the full names or CAS numbers were available. The chemical structure of the dopant has been included in the transmittance plus fluorescence plot. Appendix B contains a summary of all the fluorescence measurements performed. It also lists both the polymerization and radiation damage set numbers for further reference. The raw data from these irradiations will be provided in another document. Appendix C displays a table with the spectroscopic data currently available. Further details in the light yield (brightness) measurements, the lifetime determinations and their setup will be published.

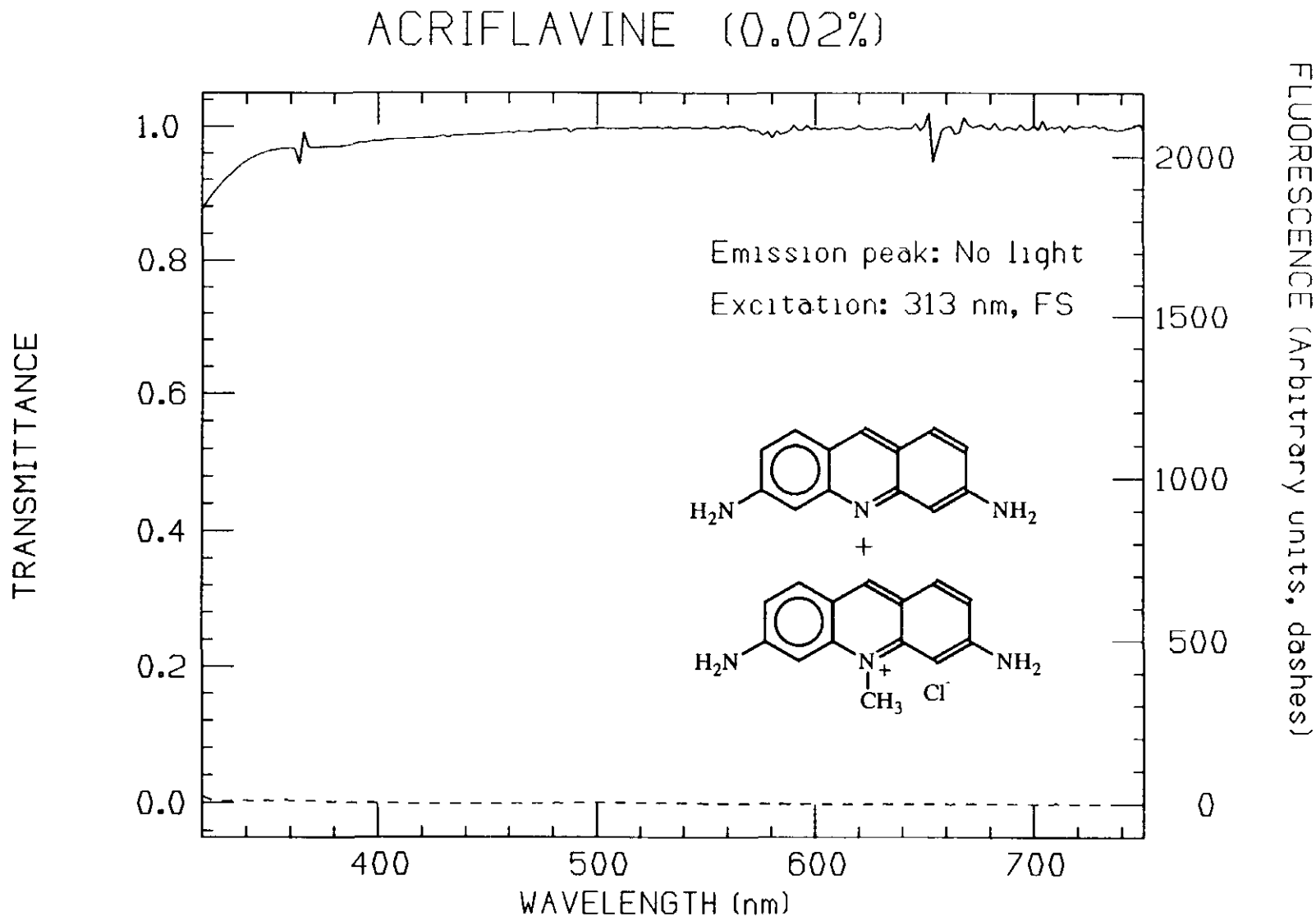
We wish to thank the members of the Particle Detector Group for their help and advice; in particular, Monica Szelag whose plotting skills and good humor became critical to the final outcome of these documents.

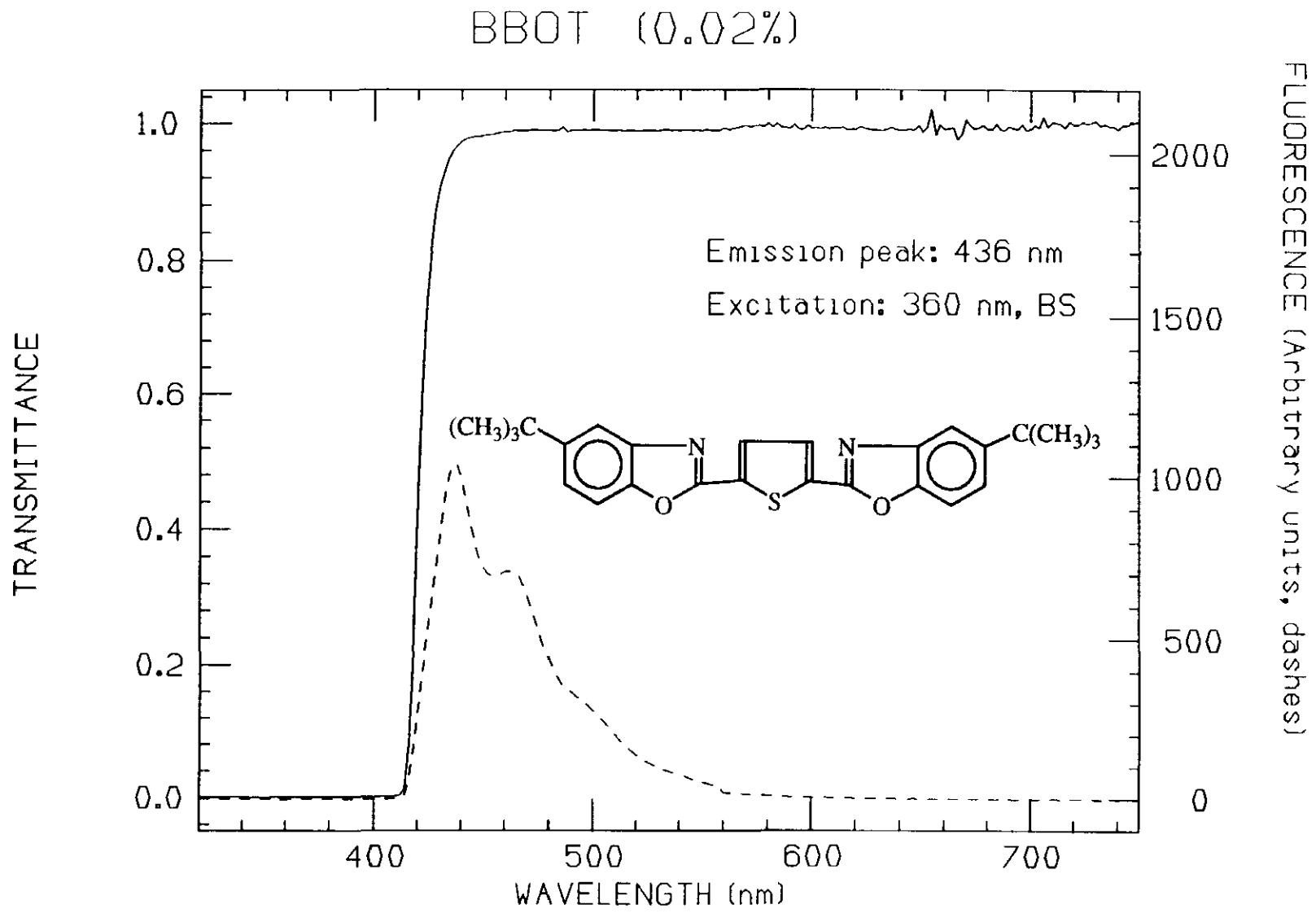

K27 (0.02%)
TRANSMITTANCE
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 496 nm
Excitation: 436 nm, BS
FLUORESCENCE (Arbitrary units, dashes)
4000
3000
2000
1000
0

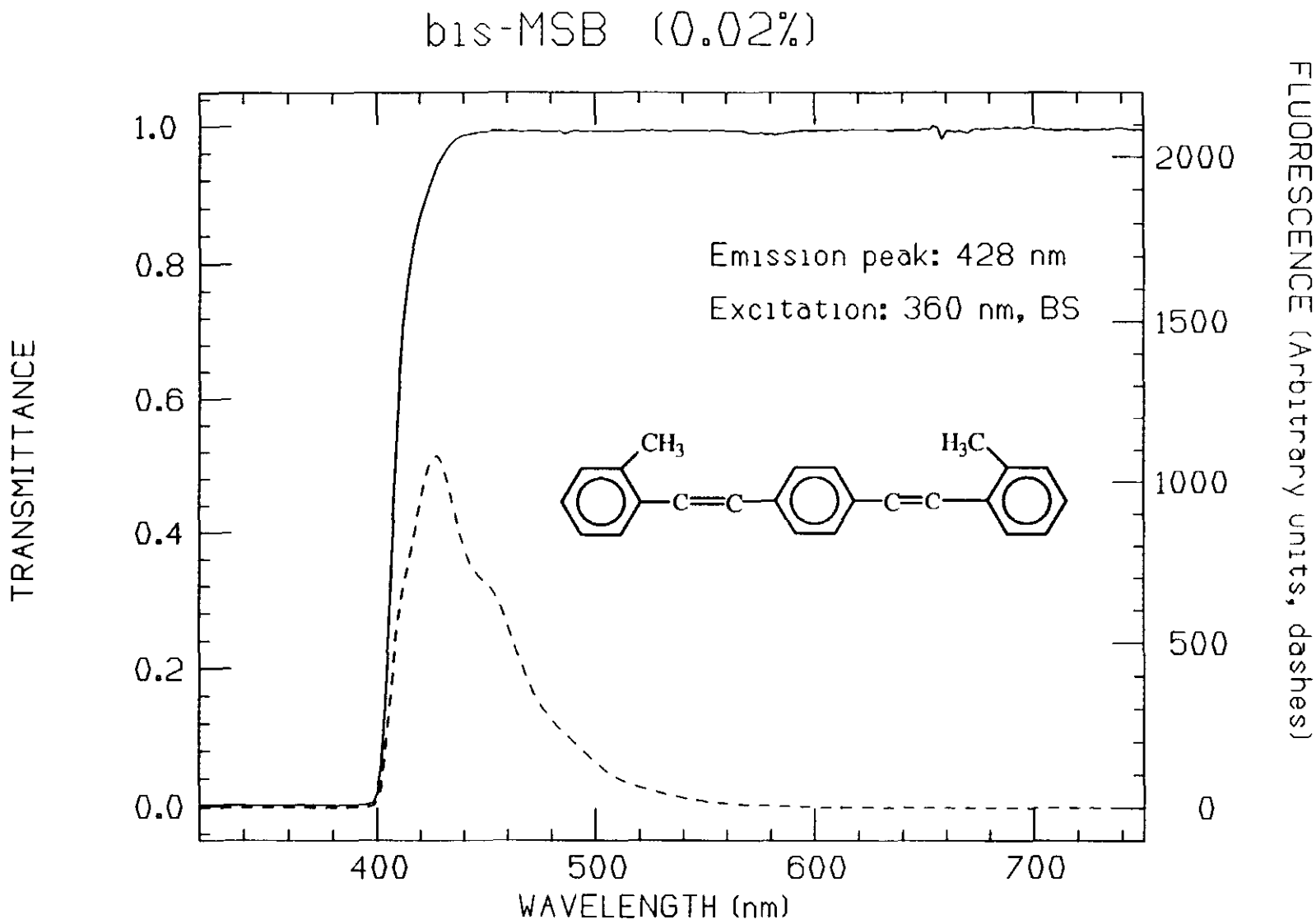

ACRIDINE ORANGE BASE (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 520 nm
Excitation: 450 nm, FS
(CH3)2N
N
N(CH3)2

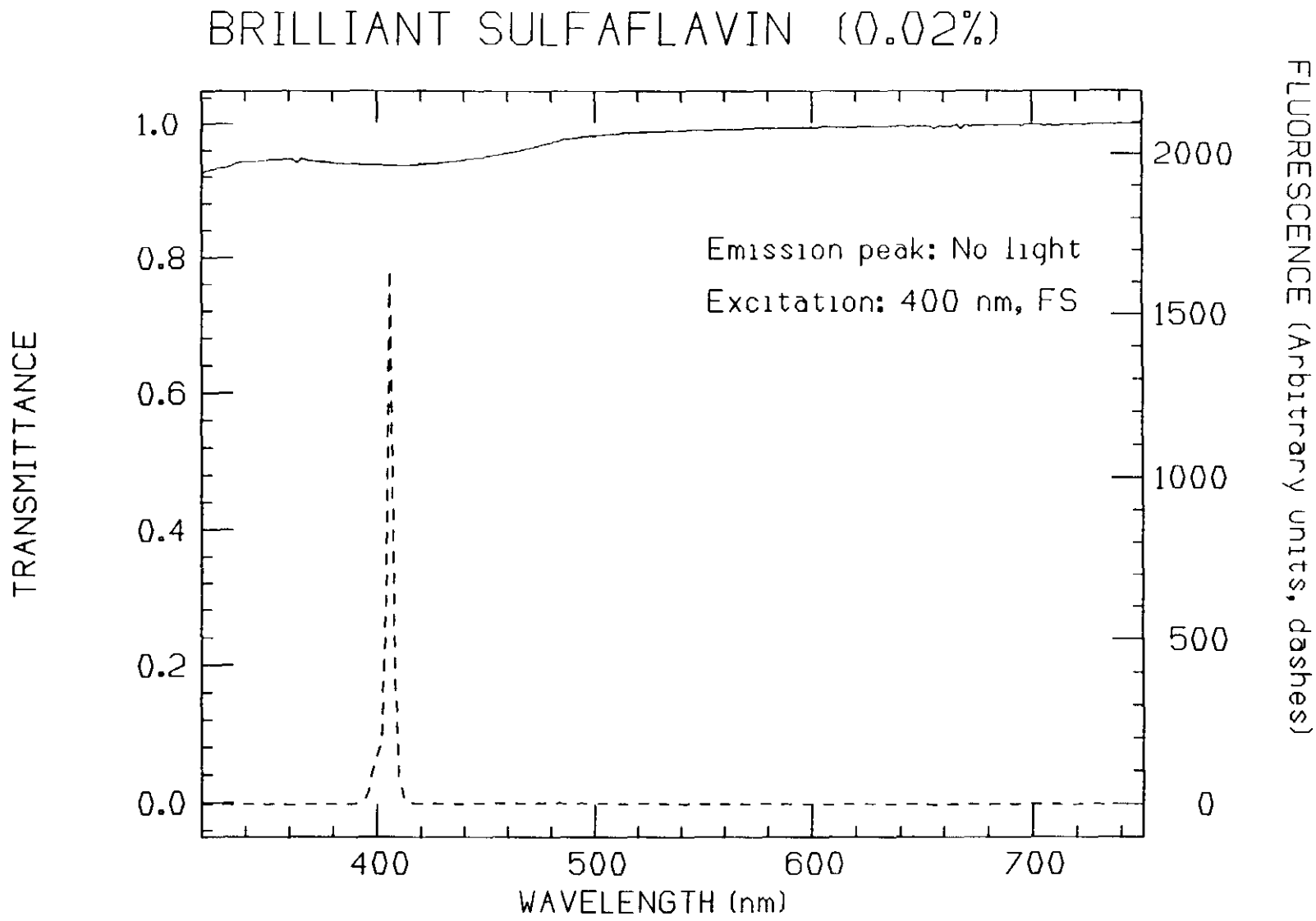
ACRIDINE YELLOW (0.02%)

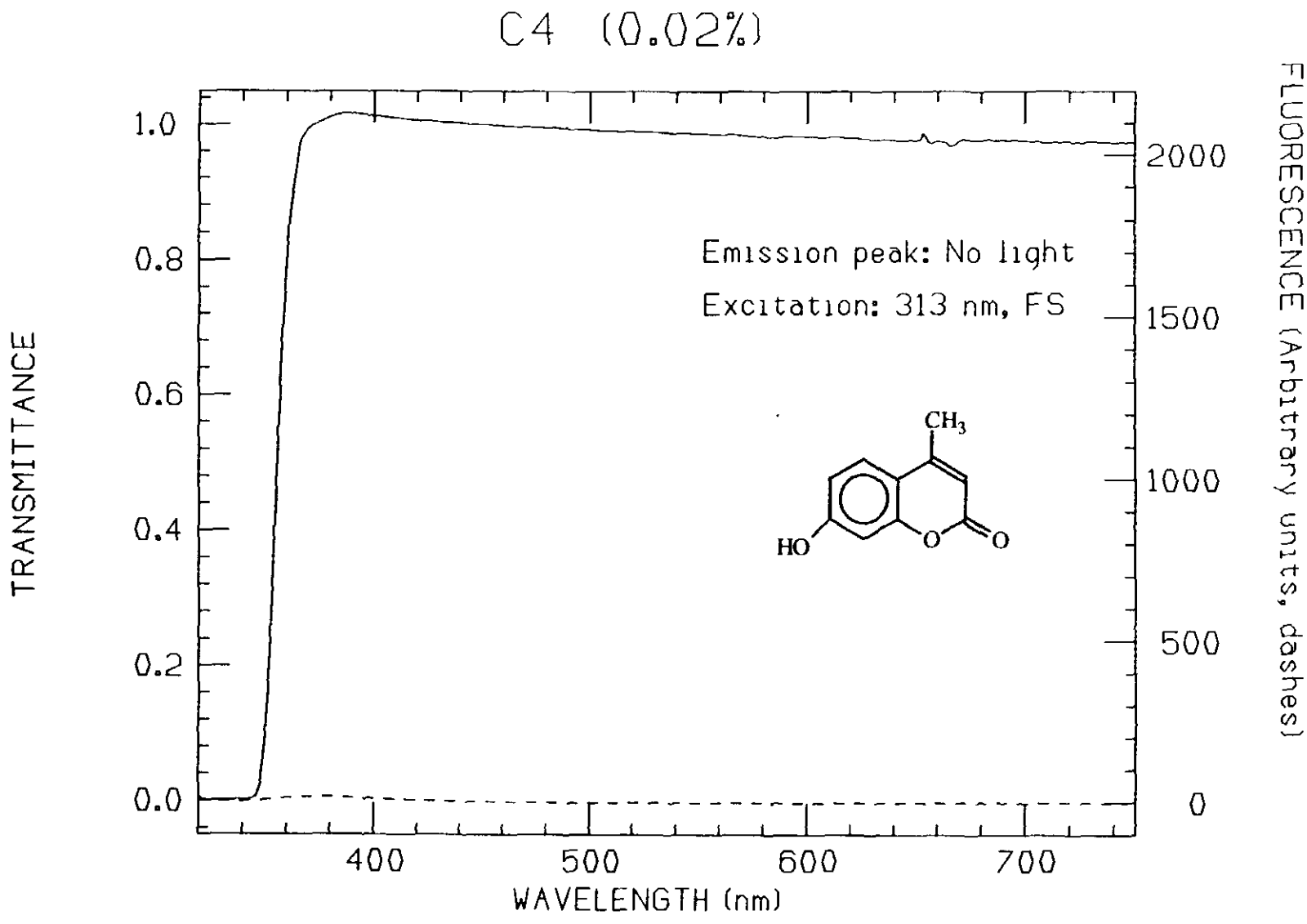


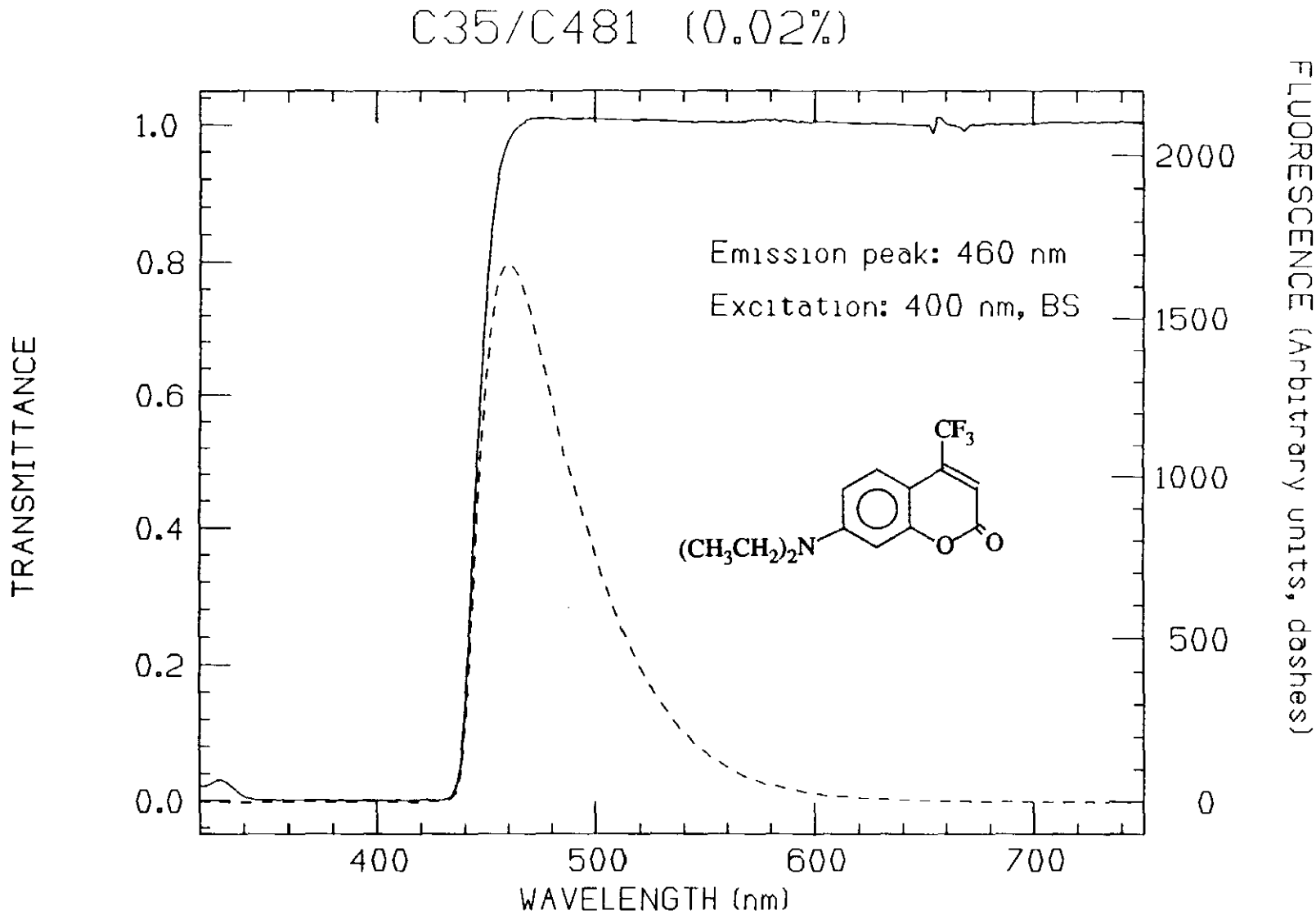

ACRIFLAVINE (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: No light
Excitation: 313 nm, FS
H2N
NH2
N
+
H2N
NH2
N+
CH3
Cl-

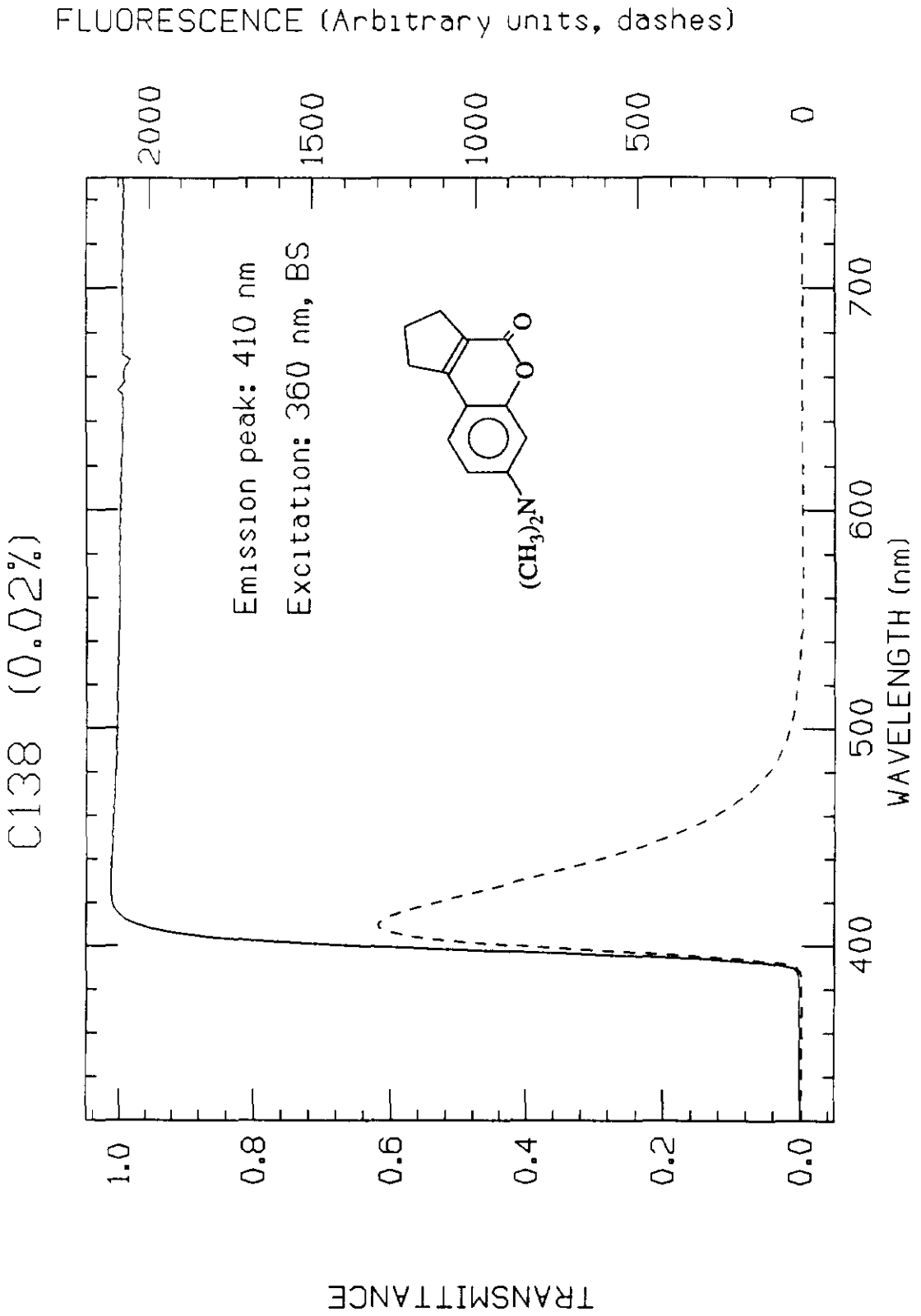

BBOT (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
Emission peak: 436 nm
Excitation: 360 nm, BS
(CH3)3C
C(CH3)3
N
N
O
S
O

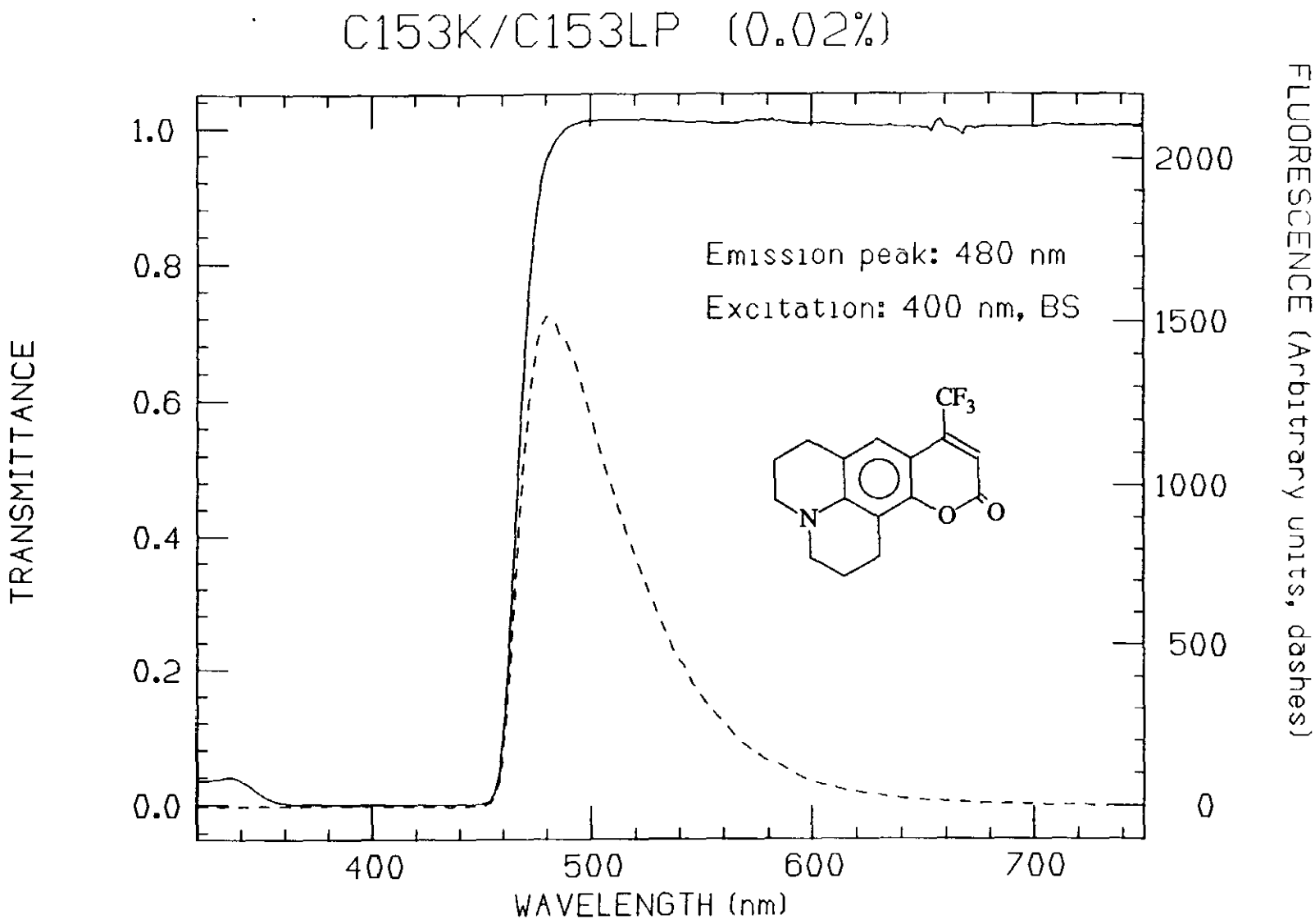

bis-MSB (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
Emission peak: 428 nm
Excitation: 360 nm, BS
CH3
H3C
C≡C
C≡C

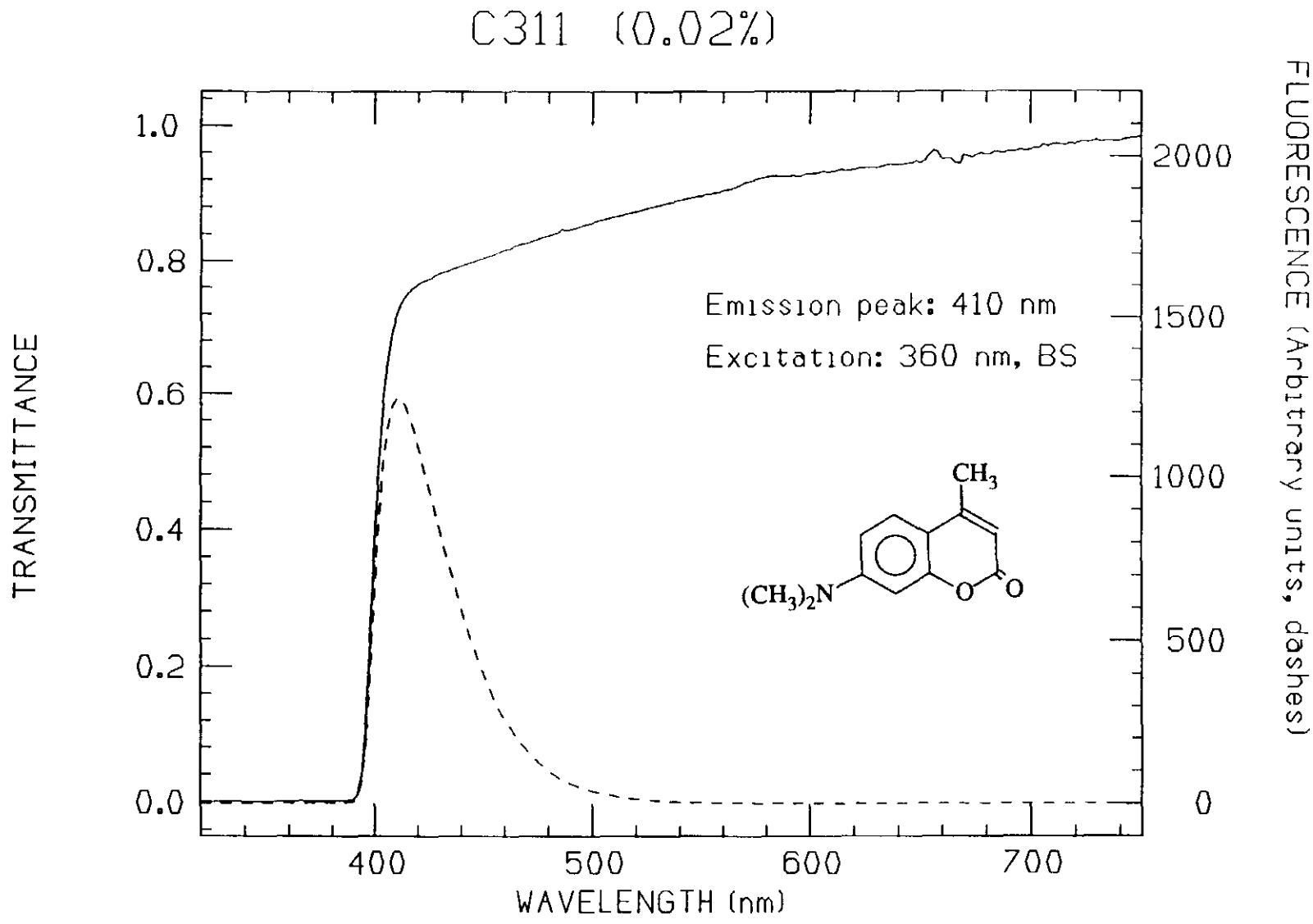

BRILLIANT SULFAFLAVIN (0.02%)
TRANSMITTANCE
1.0
0.8
0.6
0.4
0.2
0.0
Emission peak: No light
Excitation: 400 nm, FS
2000
1500
1000
500
0
FLUORESCENCE (Arbitrary units, dashes)
400
500
600
700
WAVELENGTH (nm)

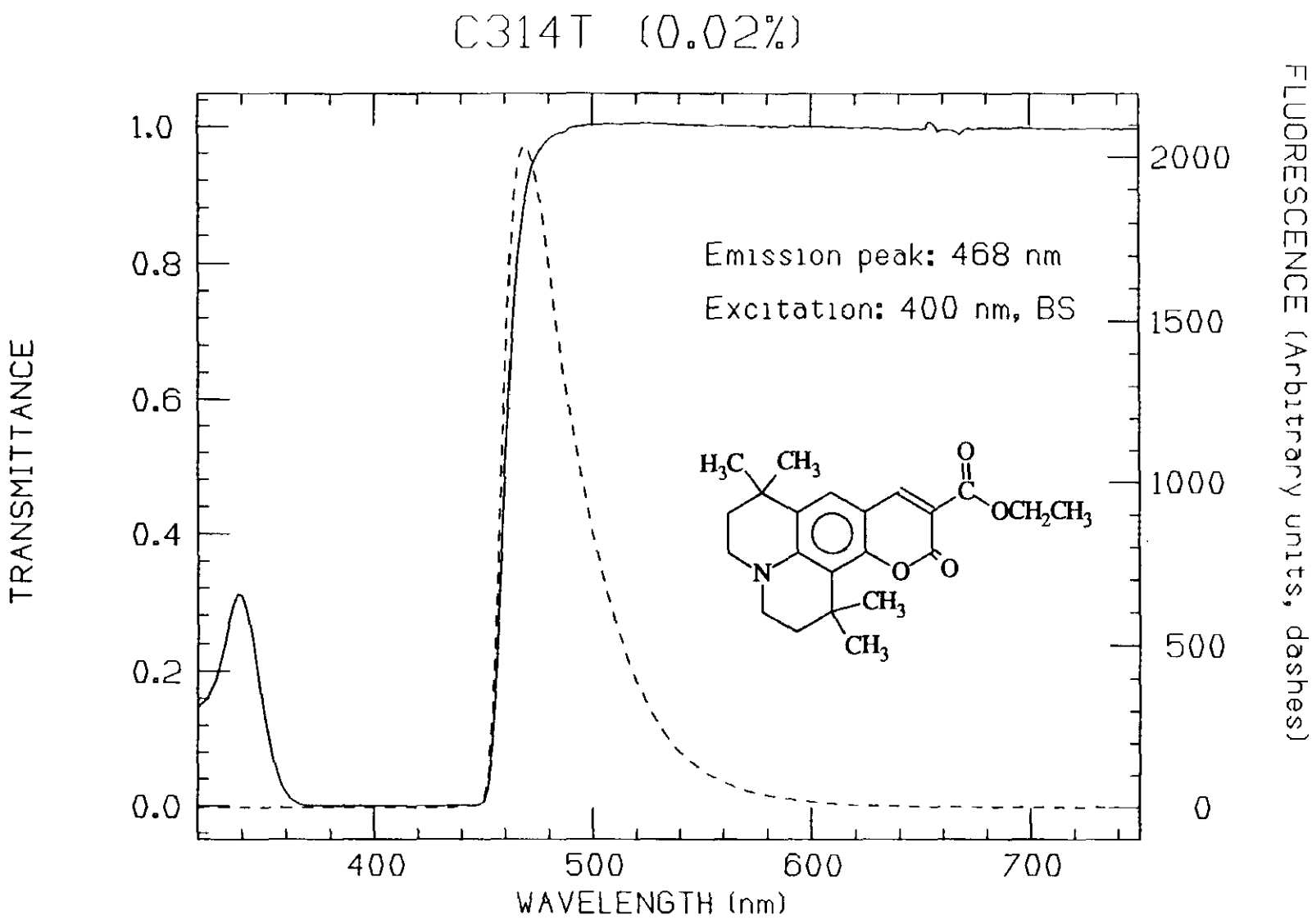

C4 (0.02%)
TRANSMITTANCE
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
WAVELENGTH (nm)
FLUORESCENCE (Arbitrary units, dashes)
2000
1500
1000
500
0
Emission peak: No light
Excitation: 313 nm, FS
CH3
HO
O
O

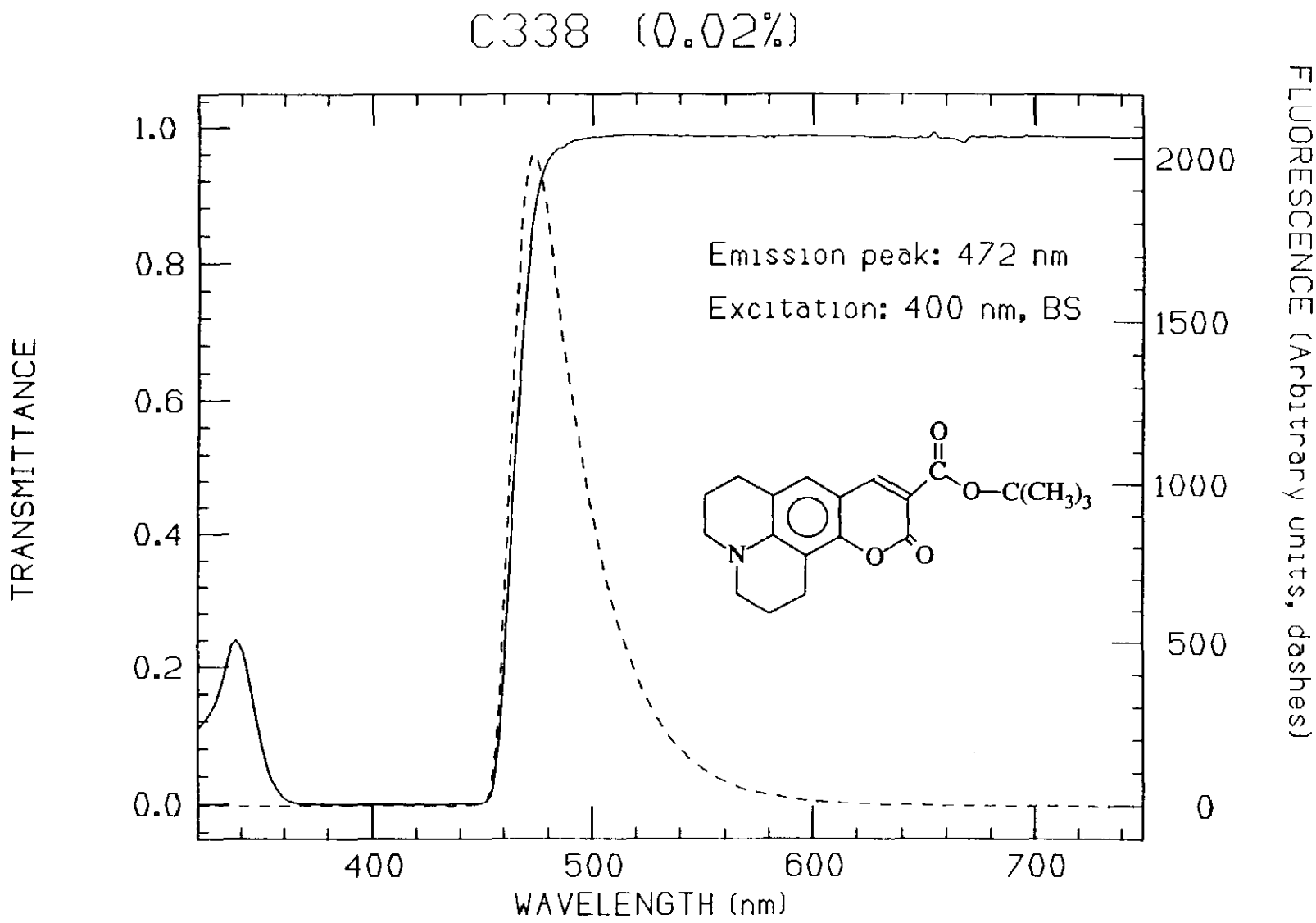

C35/C481 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 460 nm
Excitation: 400 nm, BS
CF3
(CH3CH2)2N
O
O

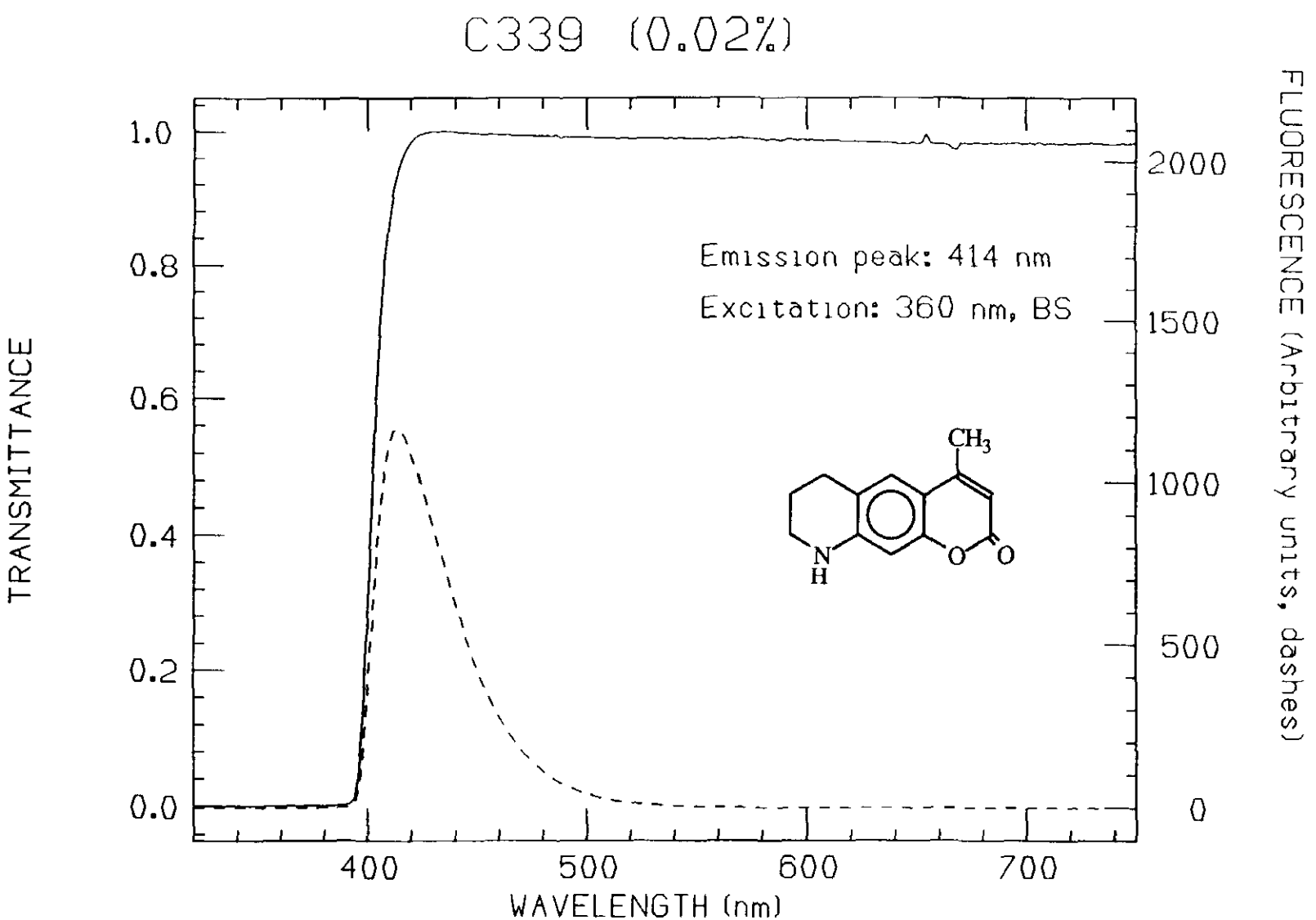

FLUORESCENCE (Arbitrary units, dashes)
2000
1500
1000
500
0
C138 (0.02%)
Emission peak: 410 nm
Excitation: 360 nm, BS
O
O
(CH3)2N
1.0
0.8
0.6
0.4
0.2
0.0
TRANSMITTANCE
400
500
600
700
WAVELENGTH (nm)

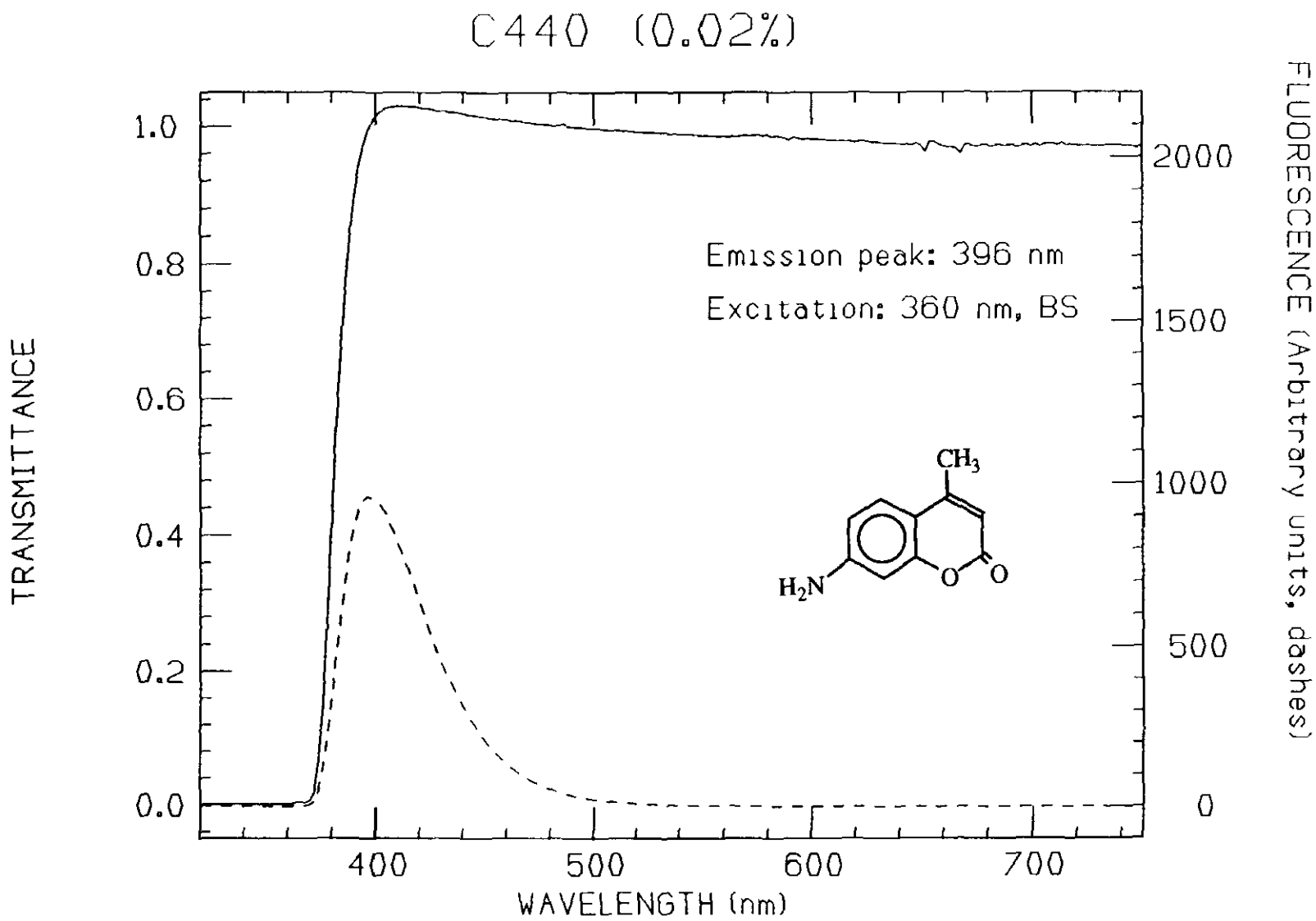

C153K/C153LP (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
Emission peak: 480 nm
Excitation: 400 nm, BS
CF3
N
O
O

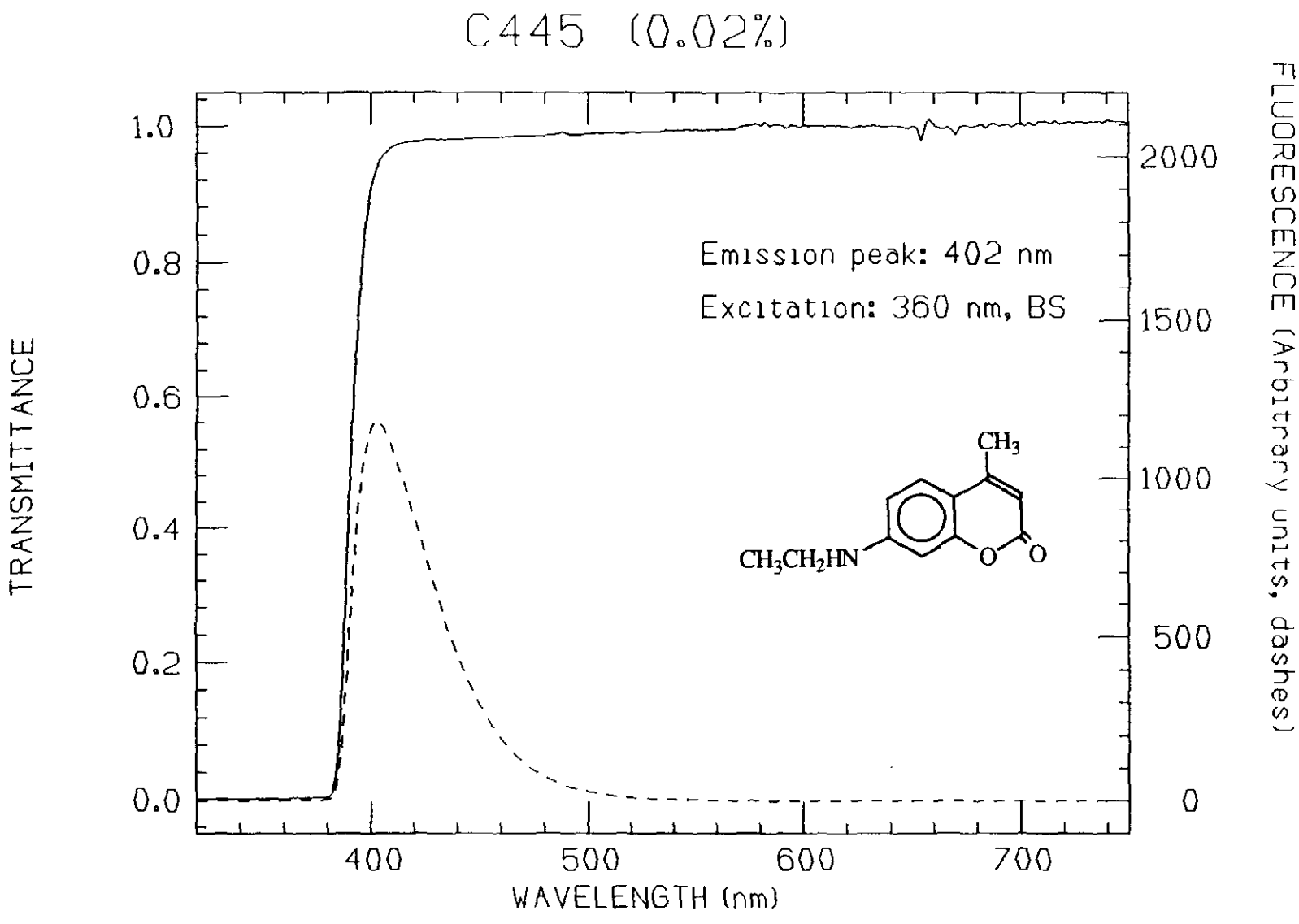

C311 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 410 nm
Excitation: 360 nm, BS
CH3
(CH3)2N
O
O

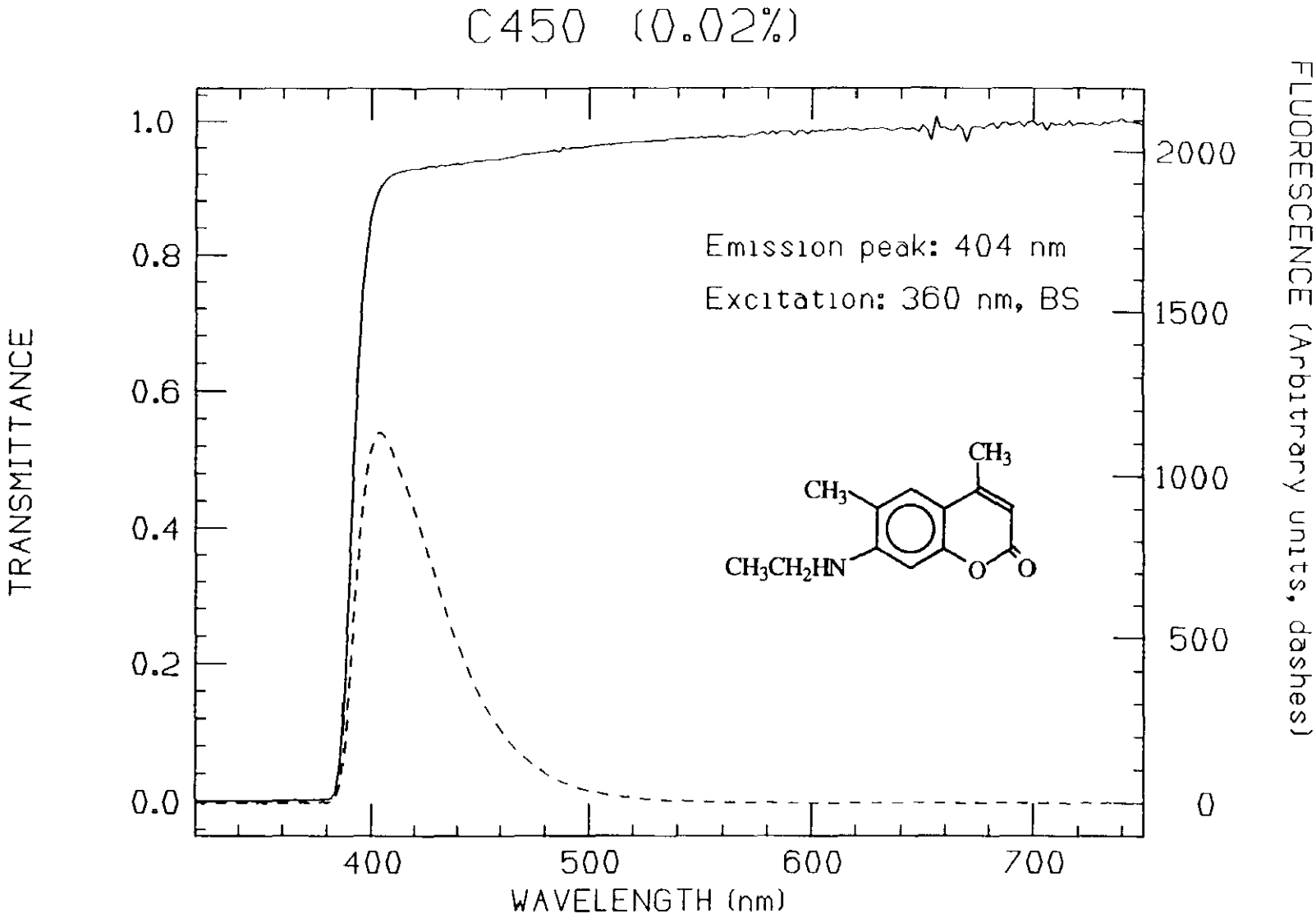

C314T (0.02%)
TRANSMITTANCE
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
WAVELENGTH (nm)
2000
1500
1000
500
0
FLUORESCENCE (Arbitrary units, dashes)
Emission peak: 468 nm
Excitation: 400 nm, BS
H3C
CH3
O
C
OCH2CH3
N
O
O
CH3
CH3

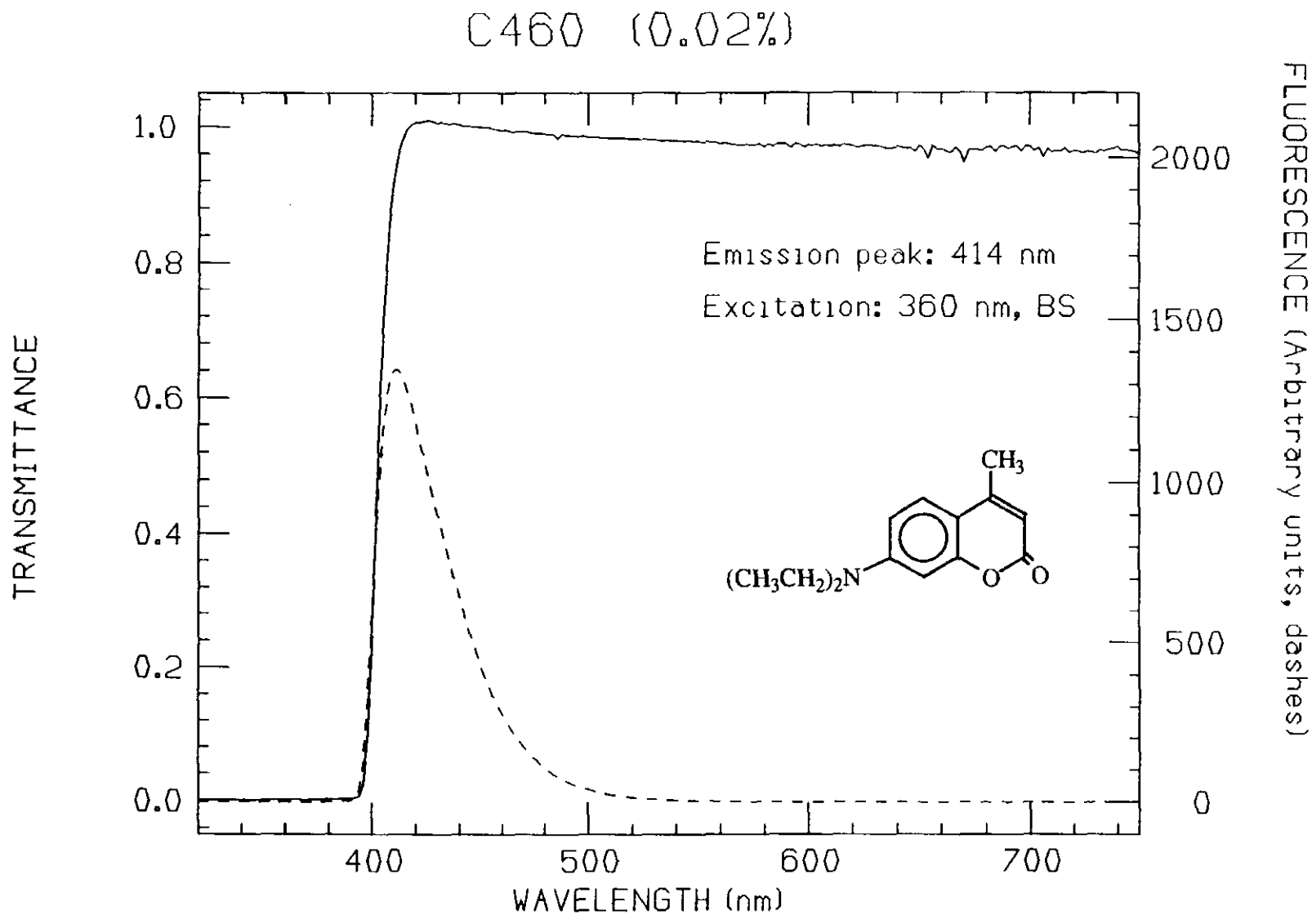

C338 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 472 nm
Excitation: 400 nm, BS
O
C
O—C(CH3)3
N
O
O

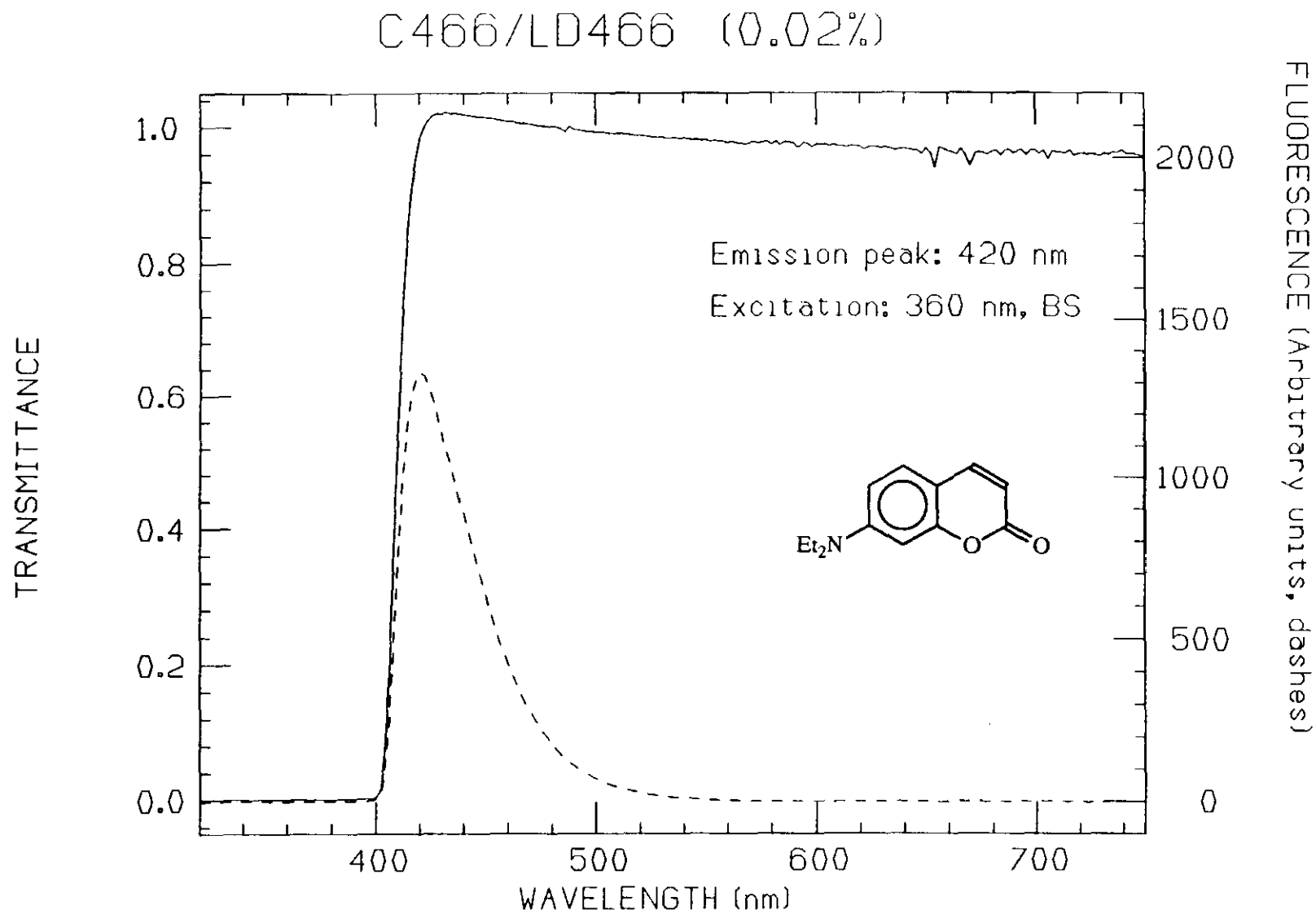

C339 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 414 nm
Excitation: 360 nm, BS
CH3
N
H
O
O

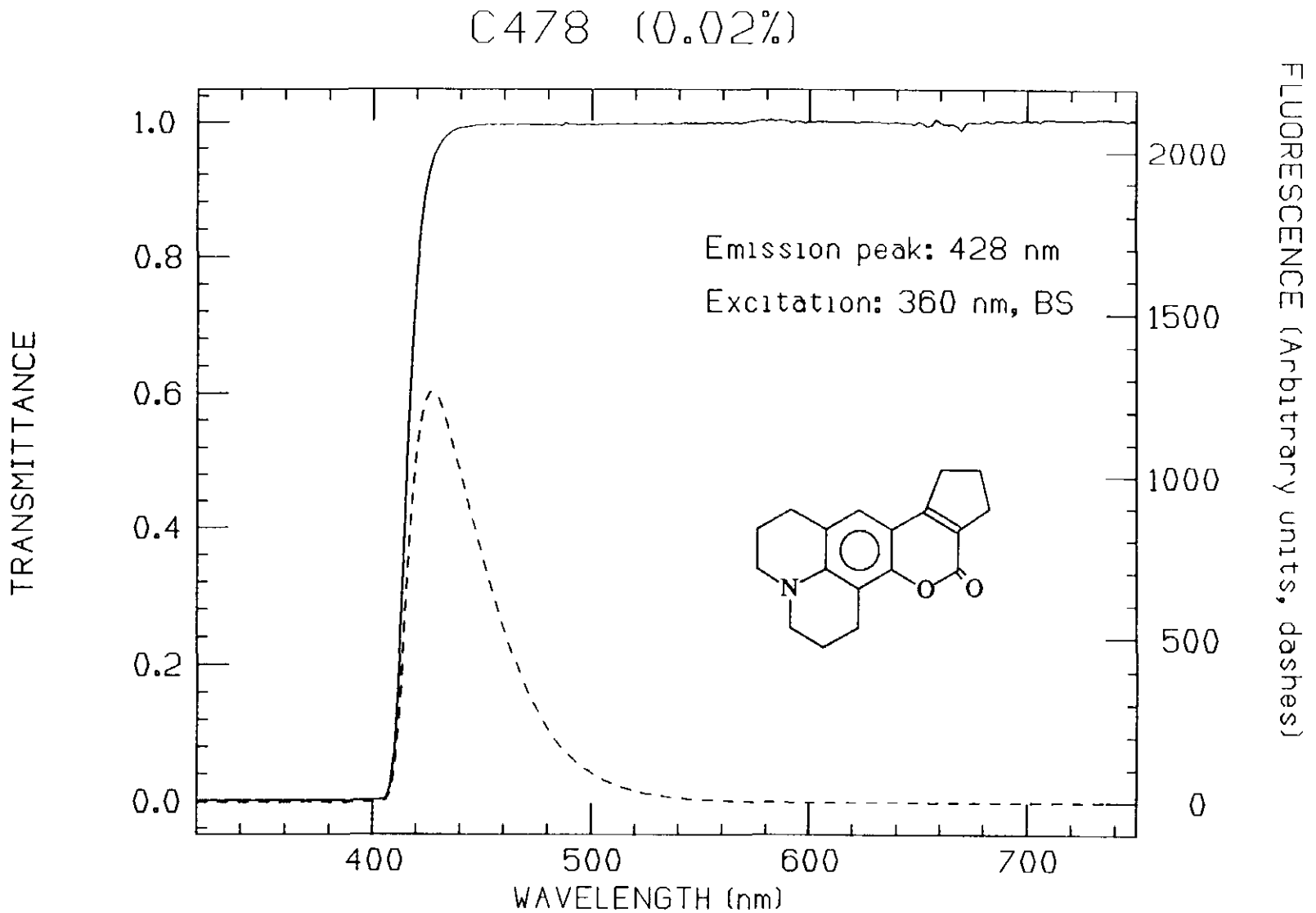

C440 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 396 nm
Excitation: 360 nm, BS
CH3
H2N
O
O

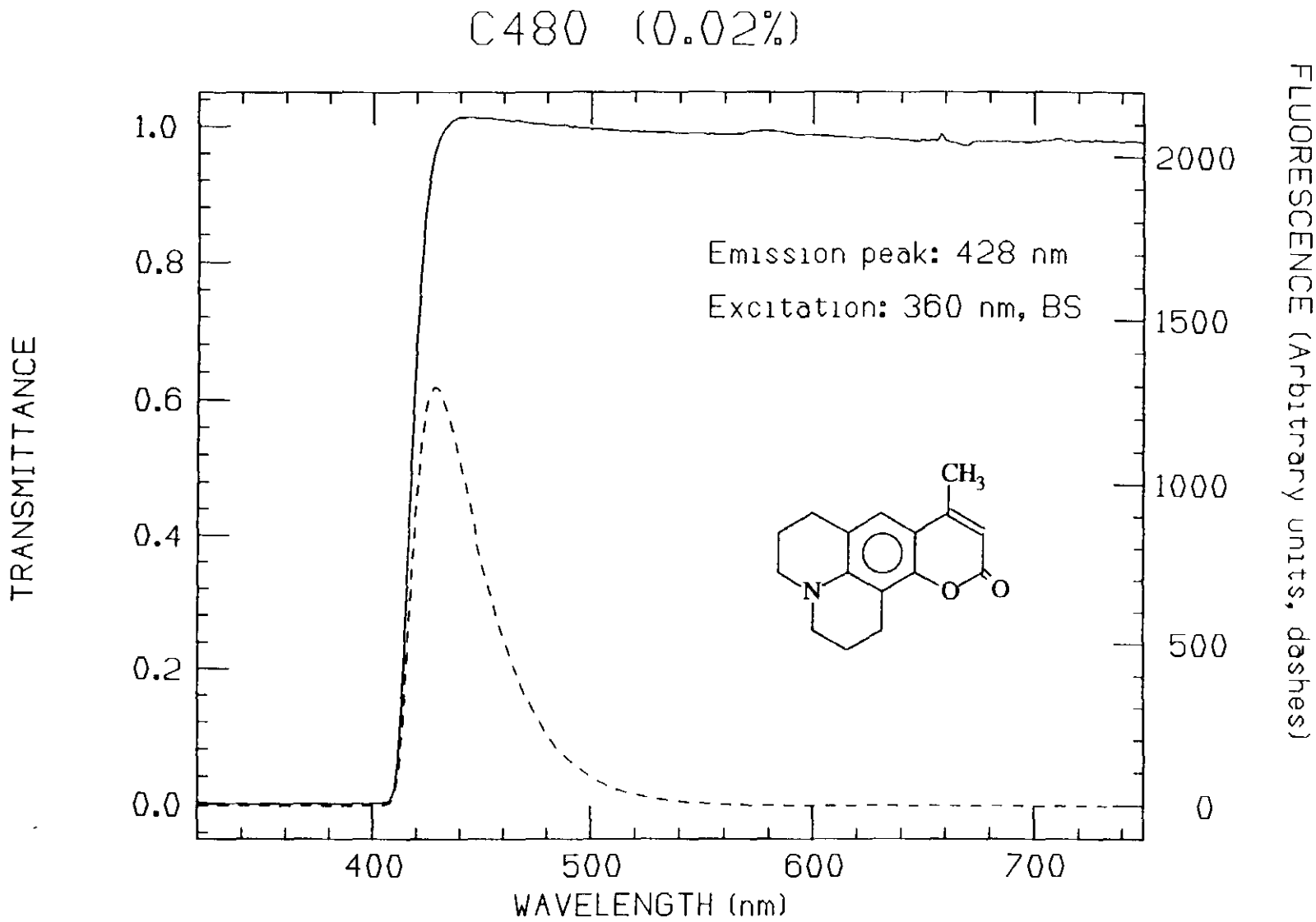

C445 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
Emission peak: 402 nm
Excitation: 360 nm, BS
CH3
CH3CH2HN
O
O

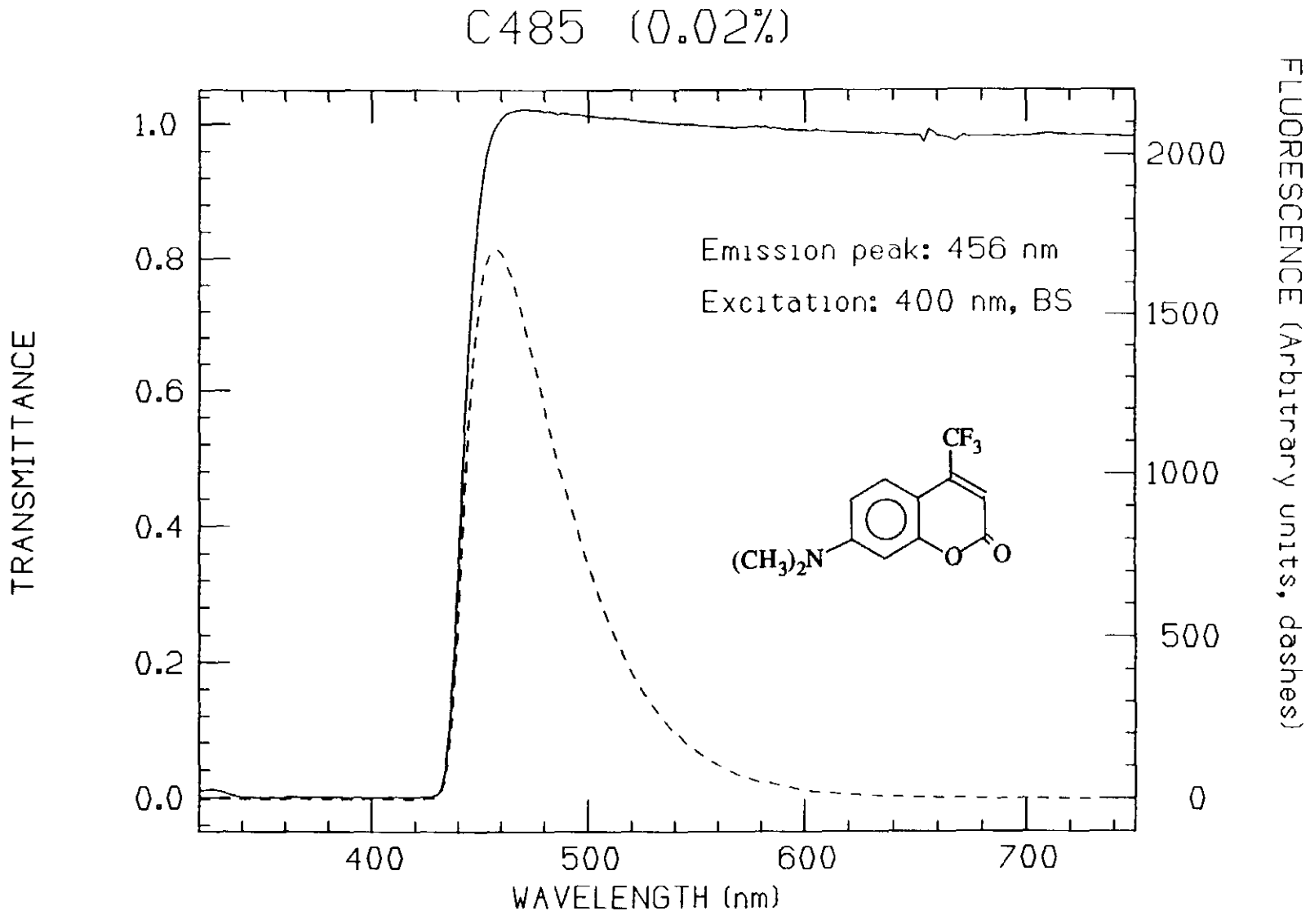

C450 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 404 nm
Excitation: 360 nm, BS
CH3
CH3
CH3CH2HN
O
O

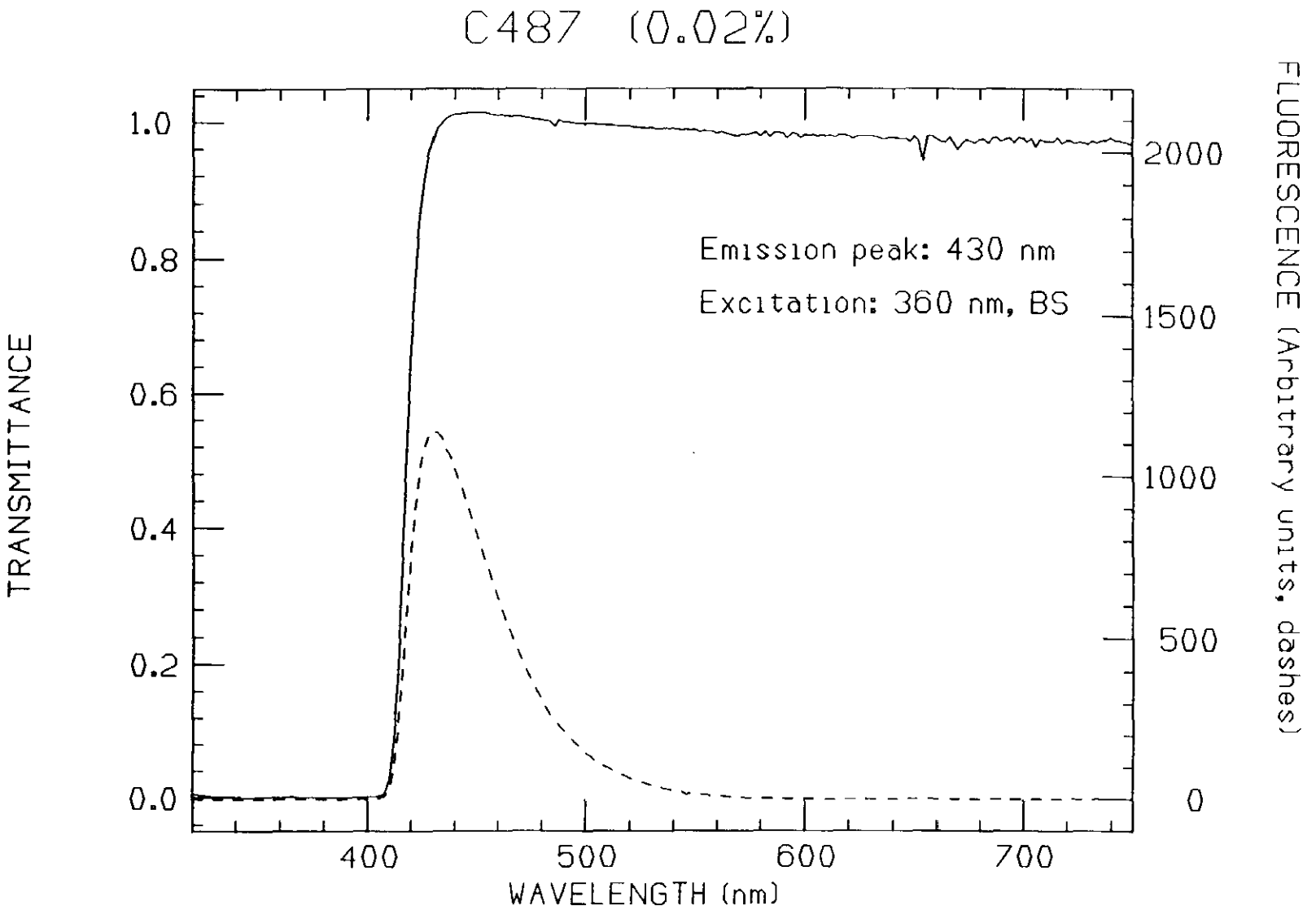

C460 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 414 nm
Excitation: 360 nm, BS
CH3
(CH3CH2)2N
O
O

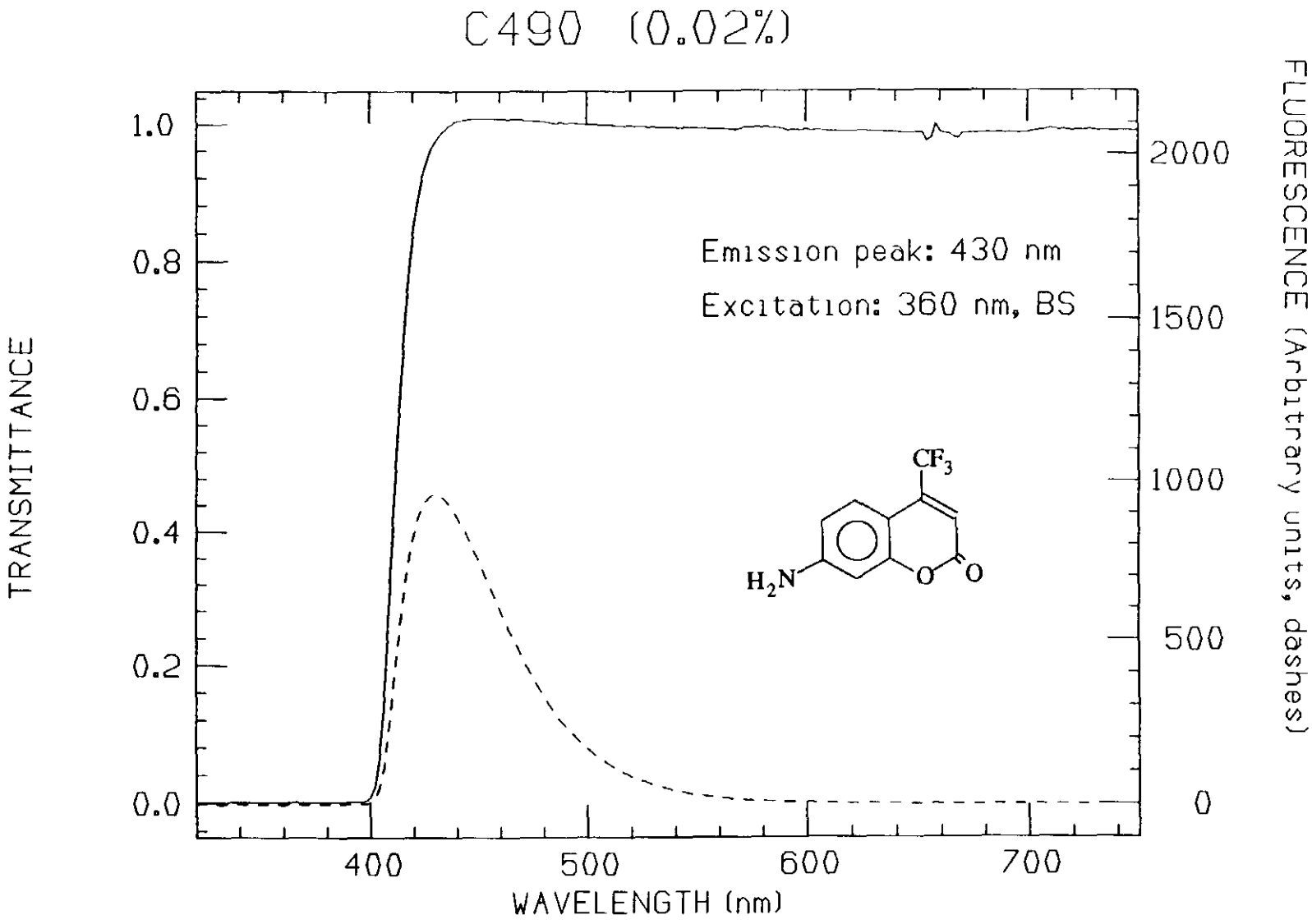

C466/LD466 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
Emission peak: 420 nm
Excitation: 360 nm, BS
Et2N
O
O

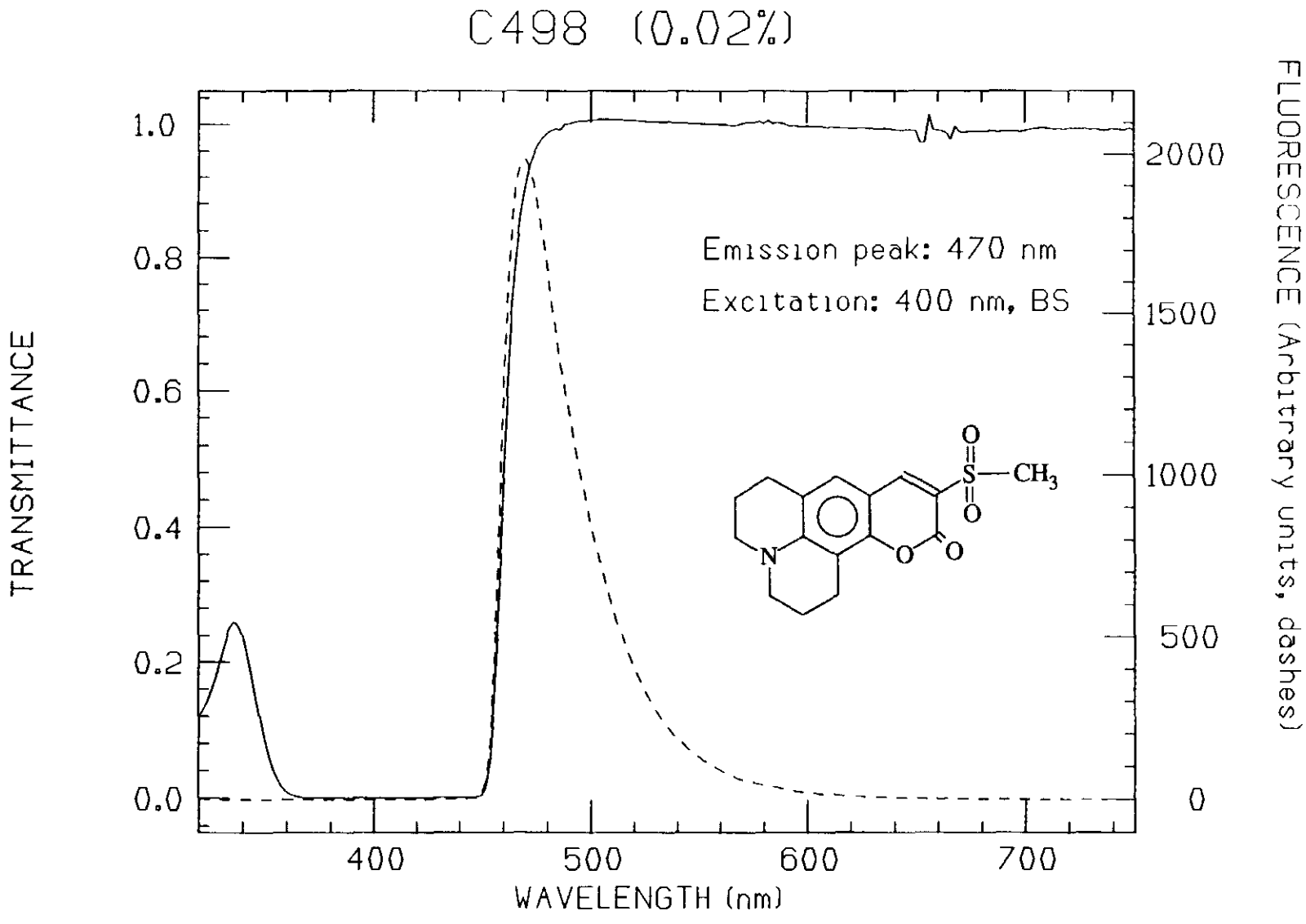

C478 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
Emission peak: 428 nm
Excitation: 360 nm, BS
N
O
O

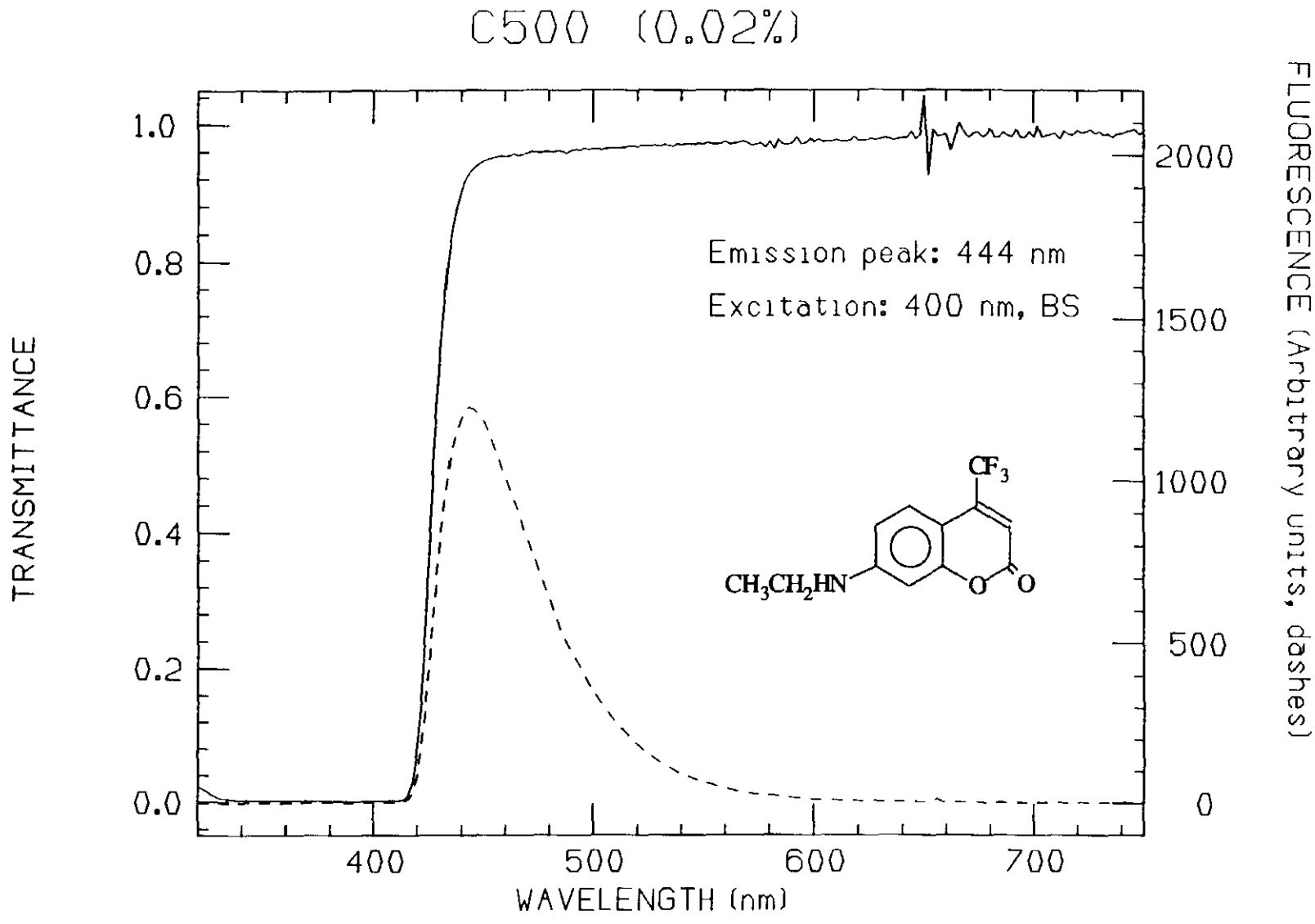

C480 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 428 nm
Excitation: 360 nm, BS
CH3
N
O
O

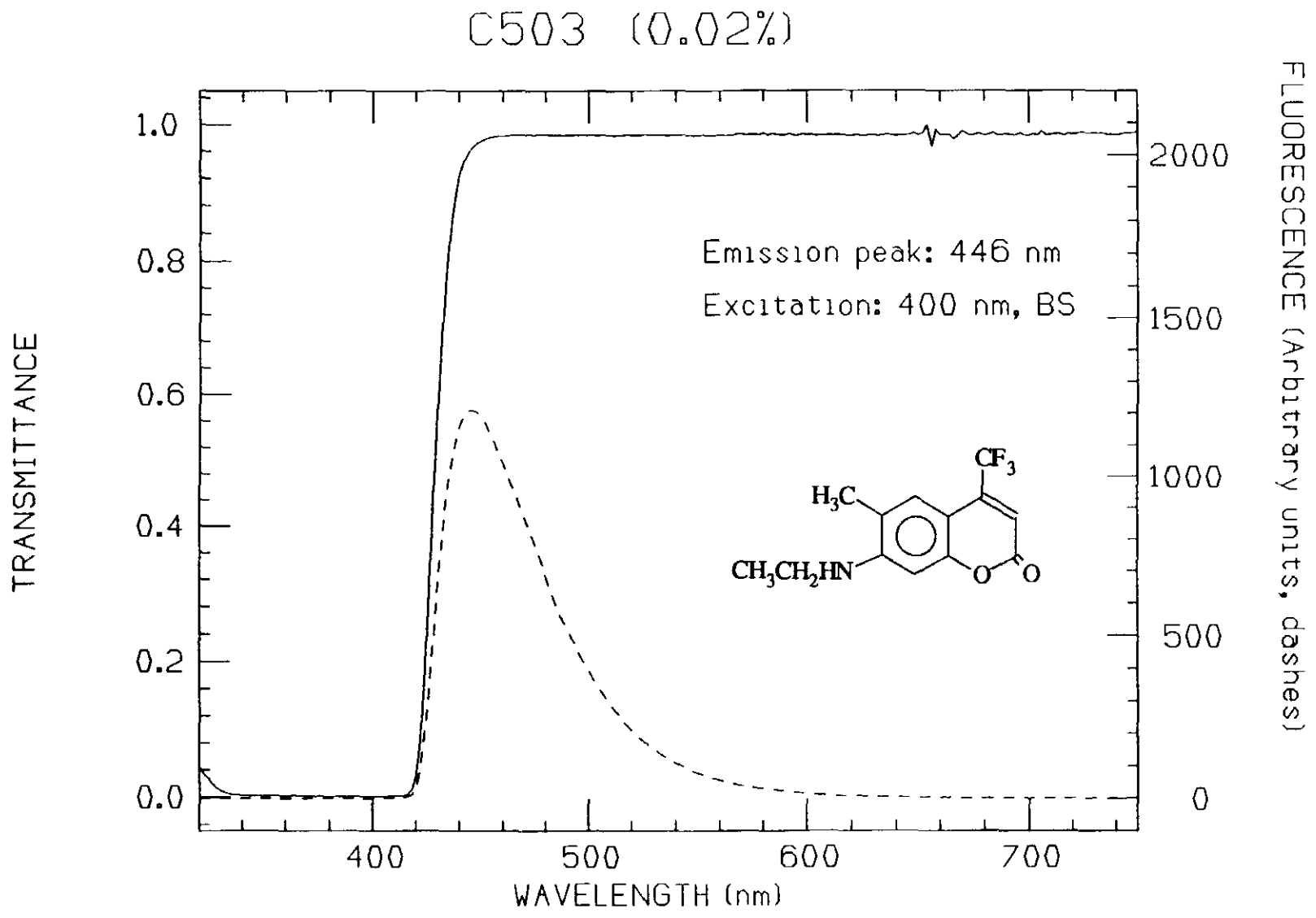

C485 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
Emission peak: 456 nm
Excitation: 400 nm, BS
CF3
(CH3)2N
O
O

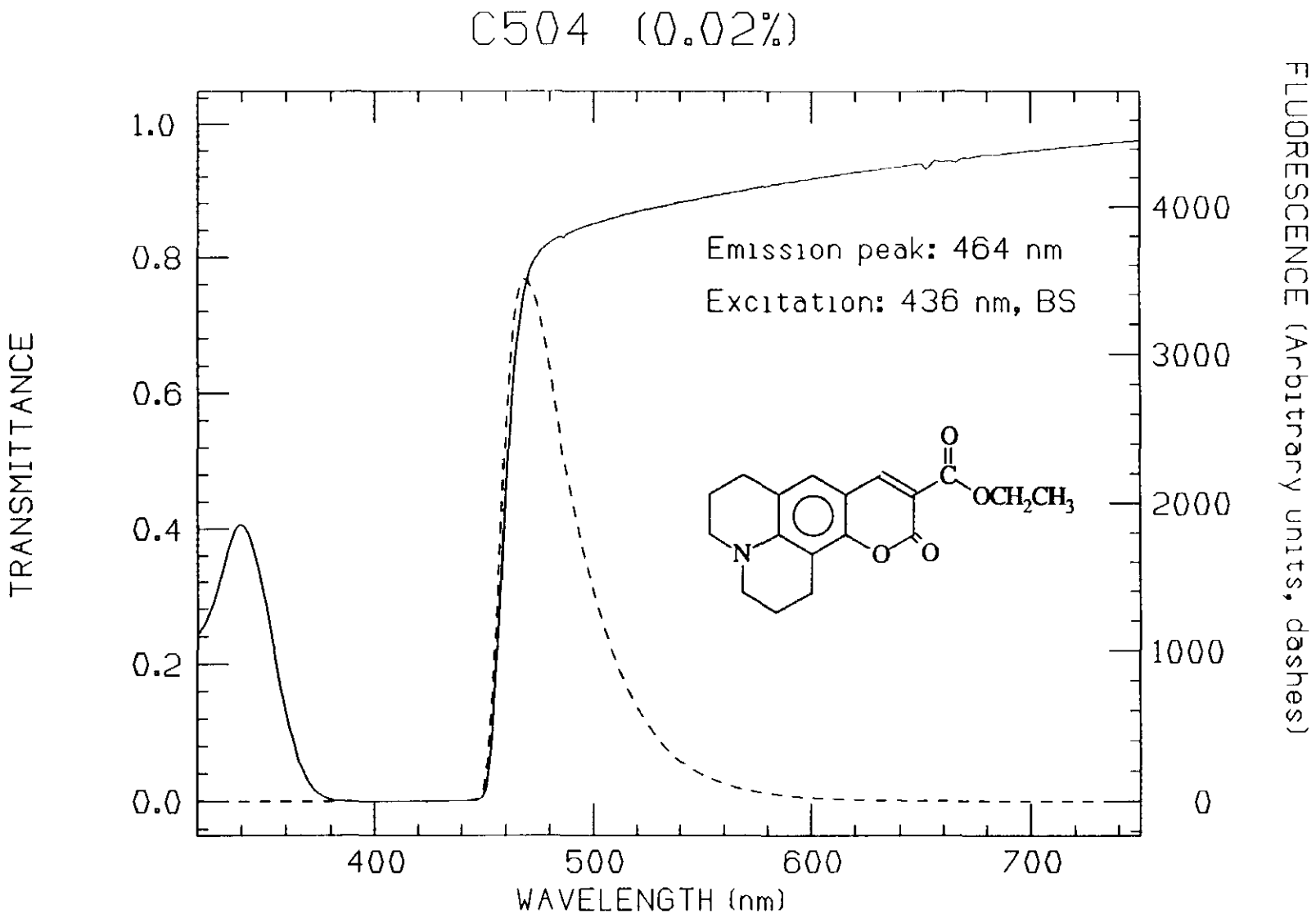

C487 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
Emission peak: 430 nm
Excitation: 360 nm, BS
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700

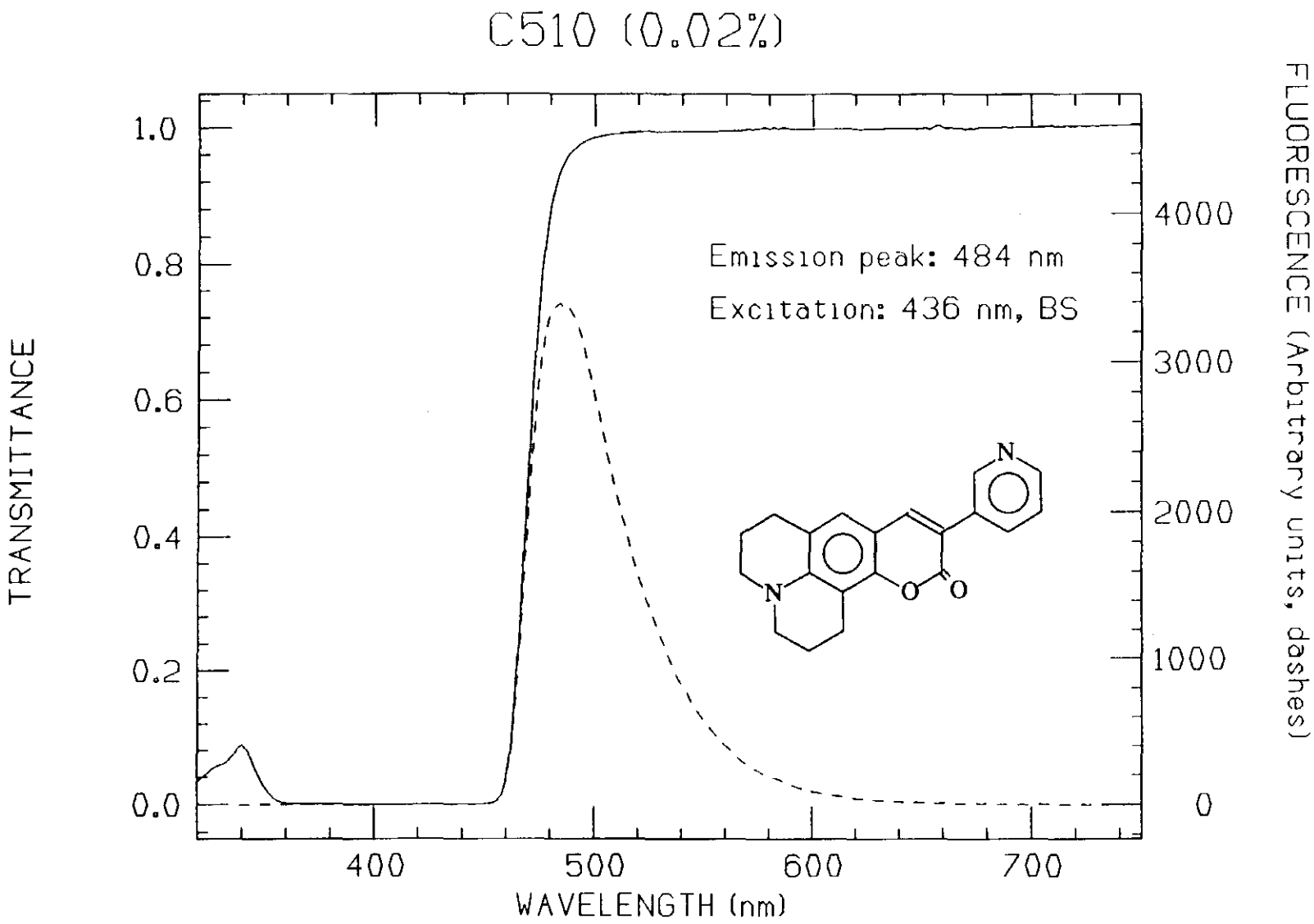

C490 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
Emission peak: 430 nm
Excitation: 360 nm, BS
CF3
H2N
O
O

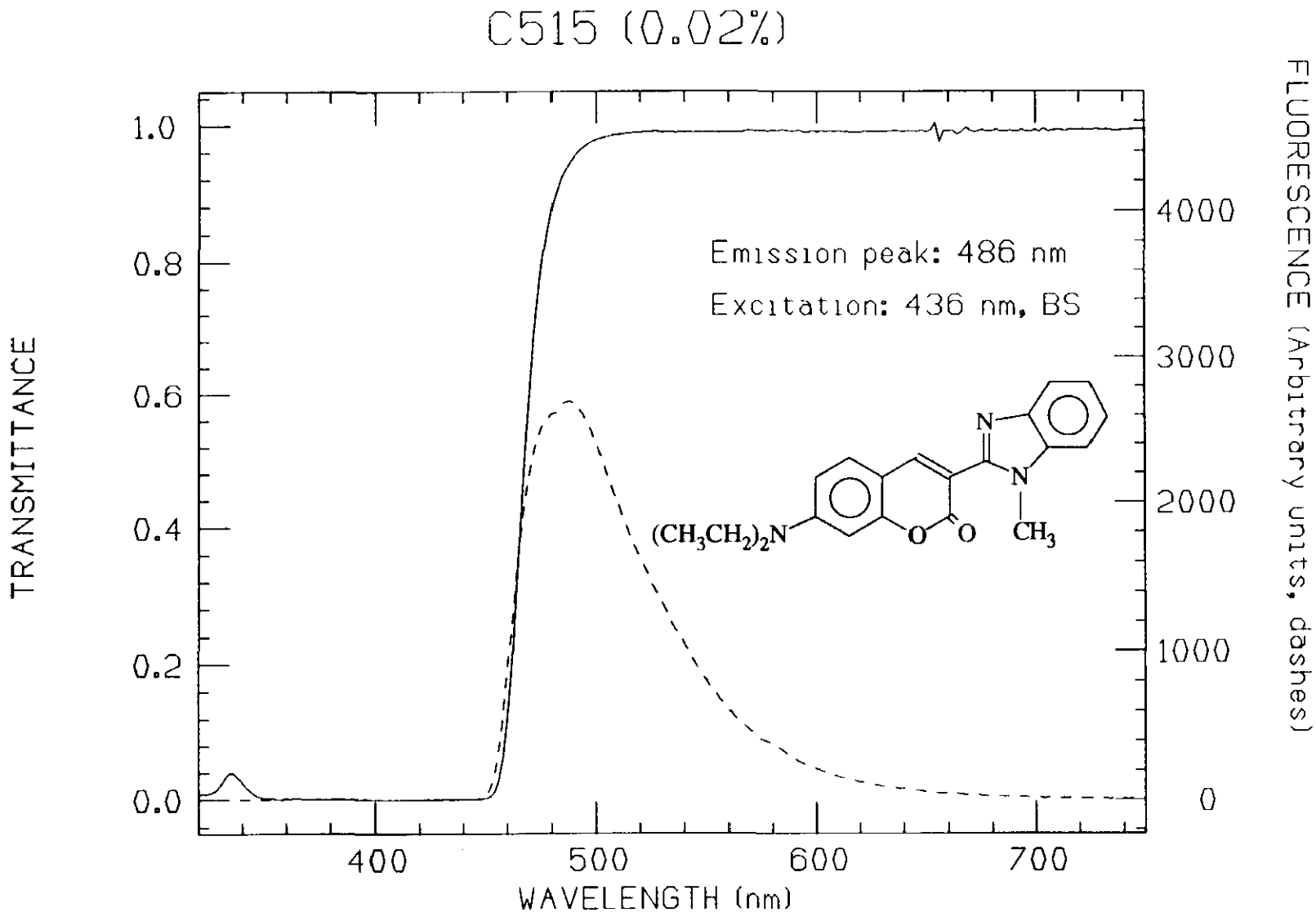

C498 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
Emission peak: 470 nm
Excitation: 400 nm, BS
O
S
CH3
O
N
O
O

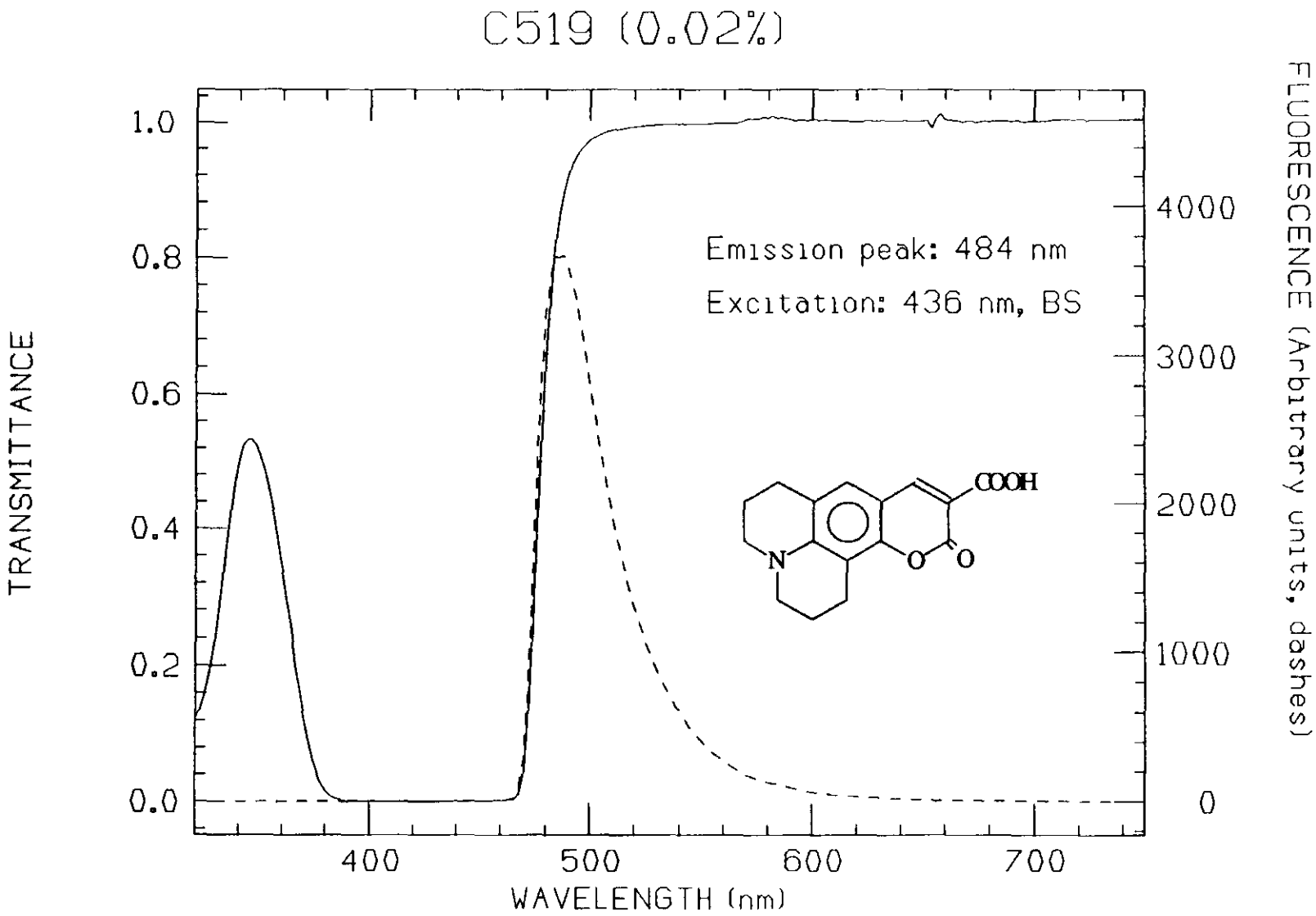

C500 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 444 nm
Excitation: 400 nm, BS
CF3
CH3CH2HN
O
O

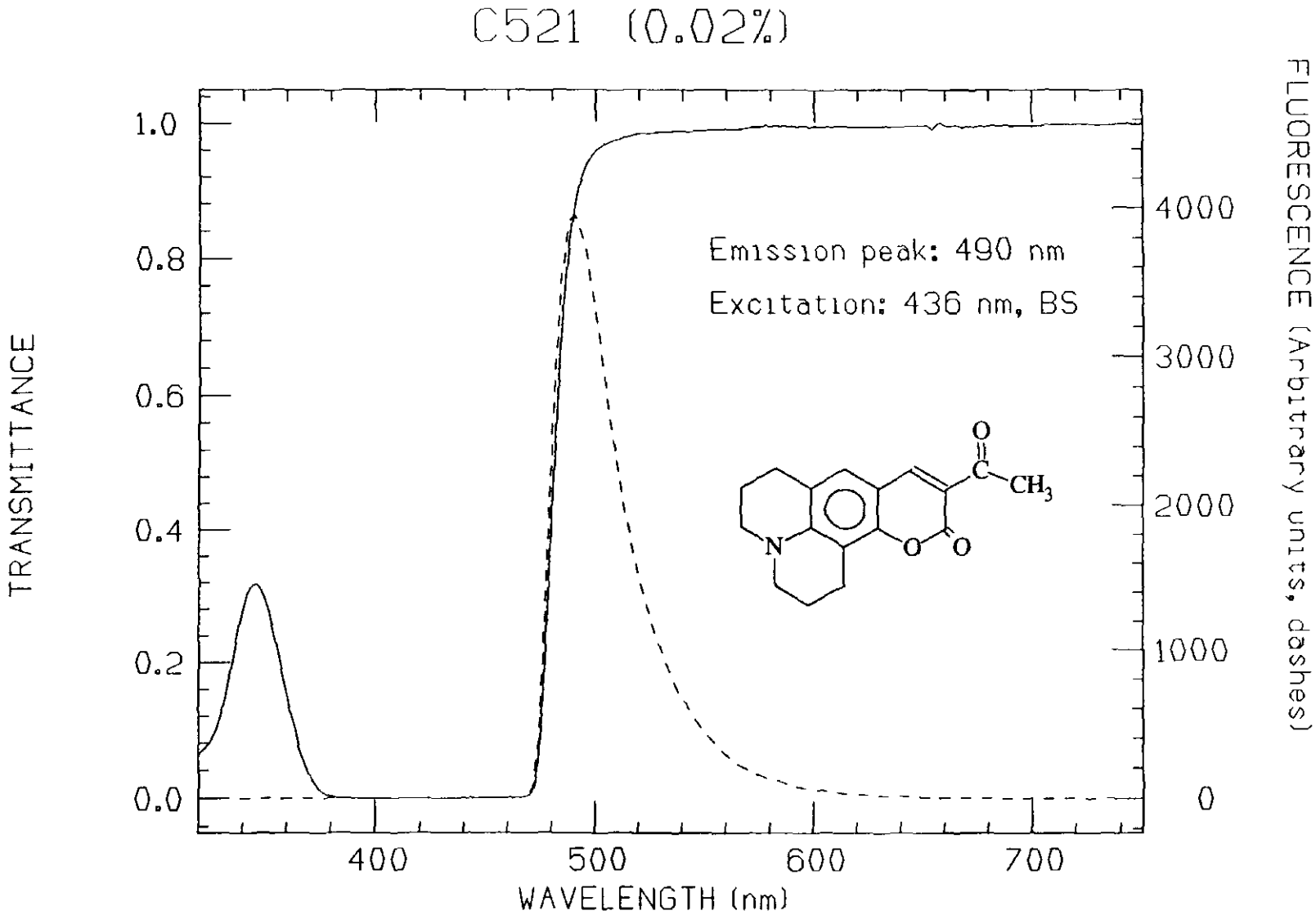

C503 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 446 nm
Excitation: 400 nm, BS
CF3
H3C
CH3CH2HN
O
O

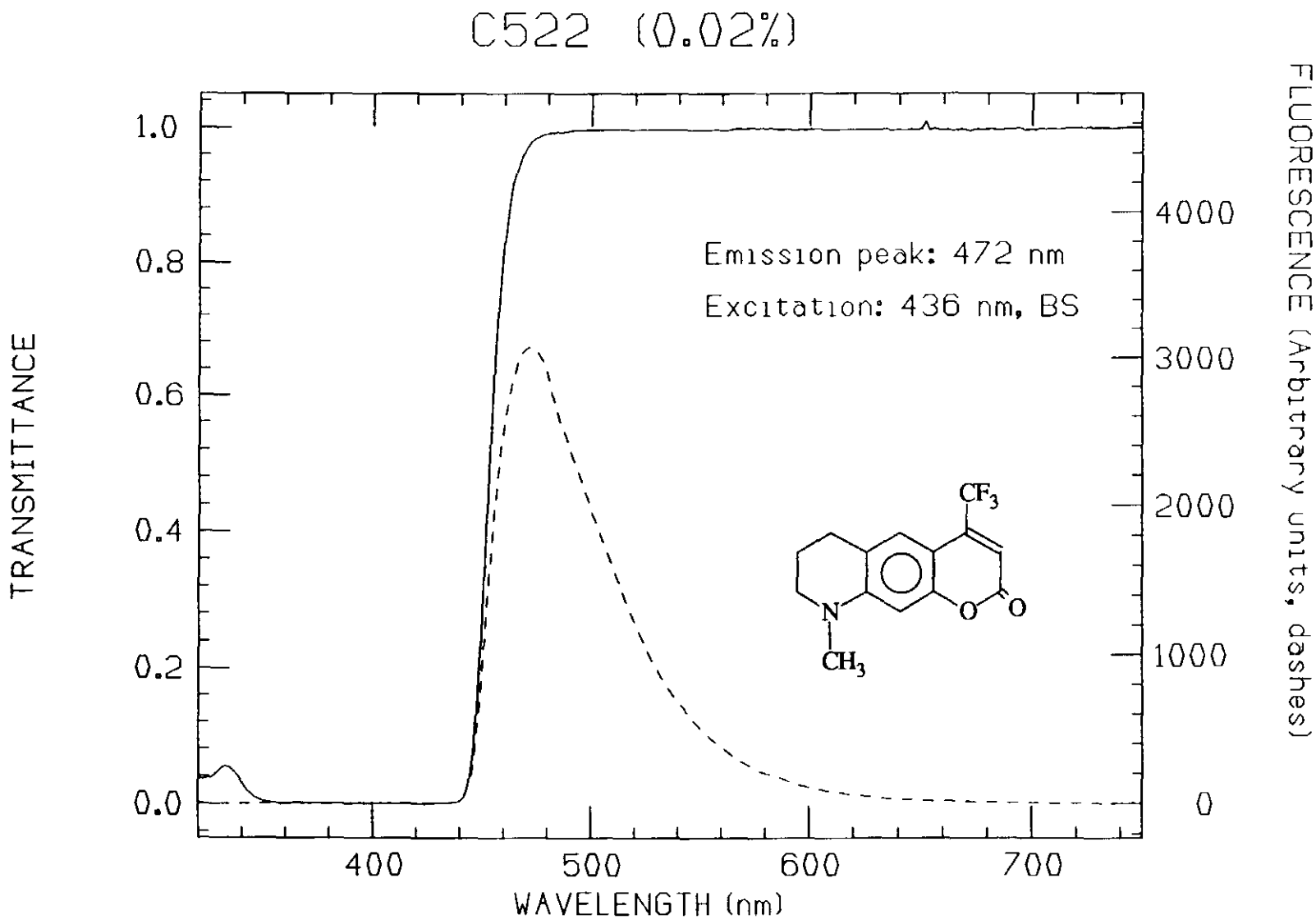

C504 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
4000
3000
2000
1000
0
Emission peak: 464 nm
Excitation: 436 nm, BS
O
C
OCH2CH3
N
O
O

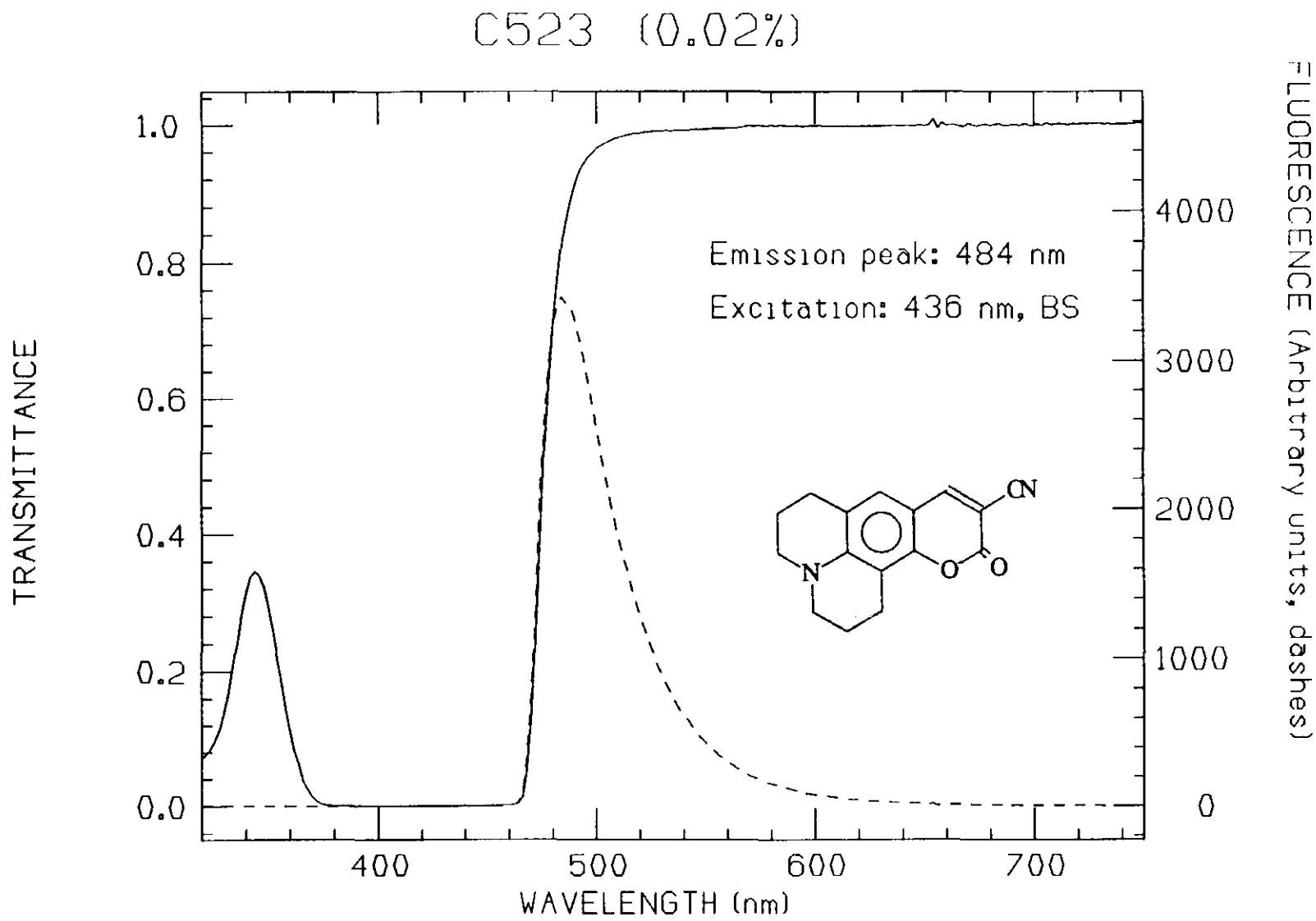

C510 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
4000
3000
2000
1000
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 484 nm
Excitation: 436 nm, BS
N
N
O
O

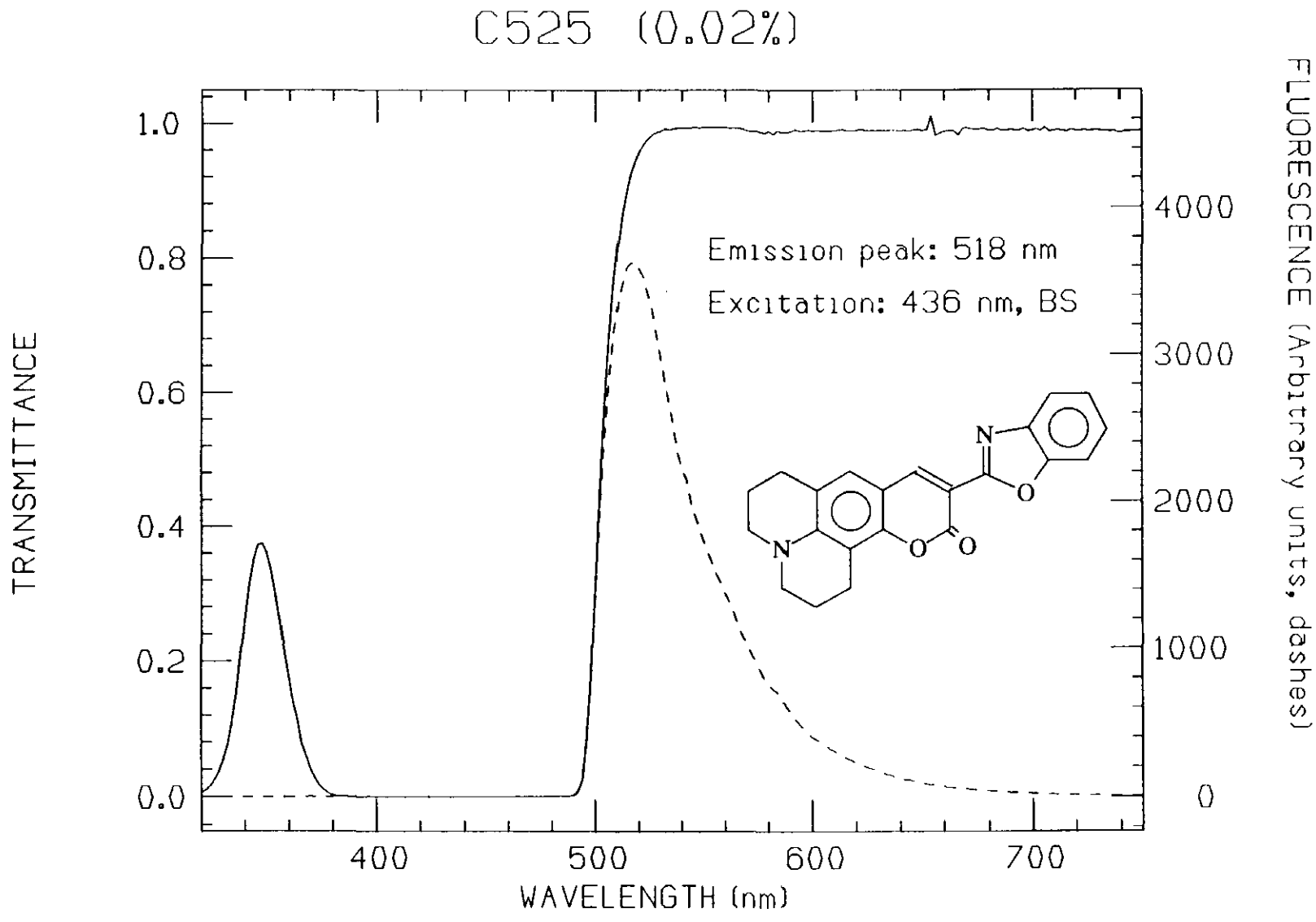

C515 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
4000
3000
2000
1000
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 486 nm
Excitation: 436 nm, BS
(CH3CH2)2N
O
O
N
N
CH3

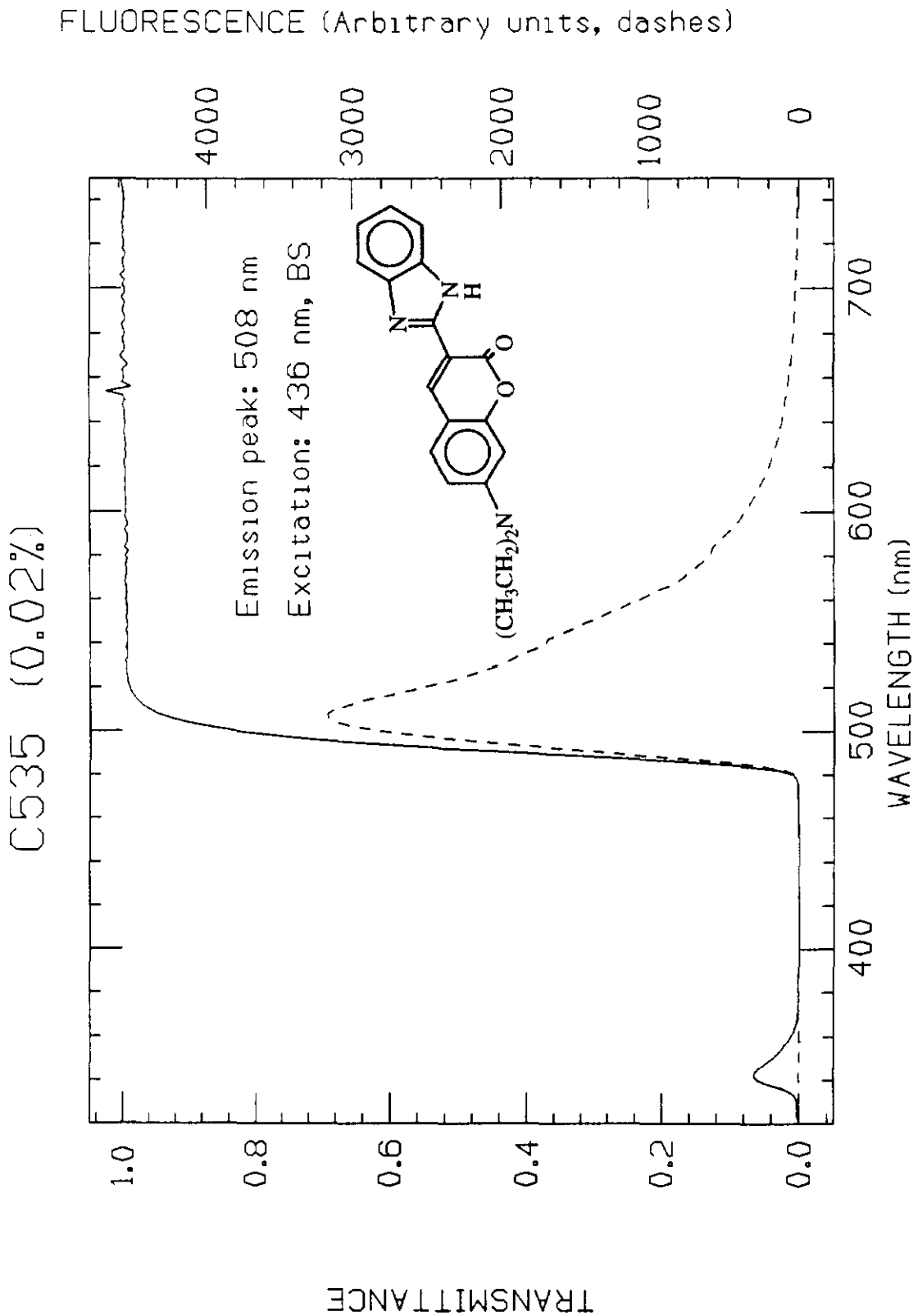

C519 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
4000
3000
2000
1000
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 484 nm
Excitation: 436 nm, BS
COOH
N
O
O

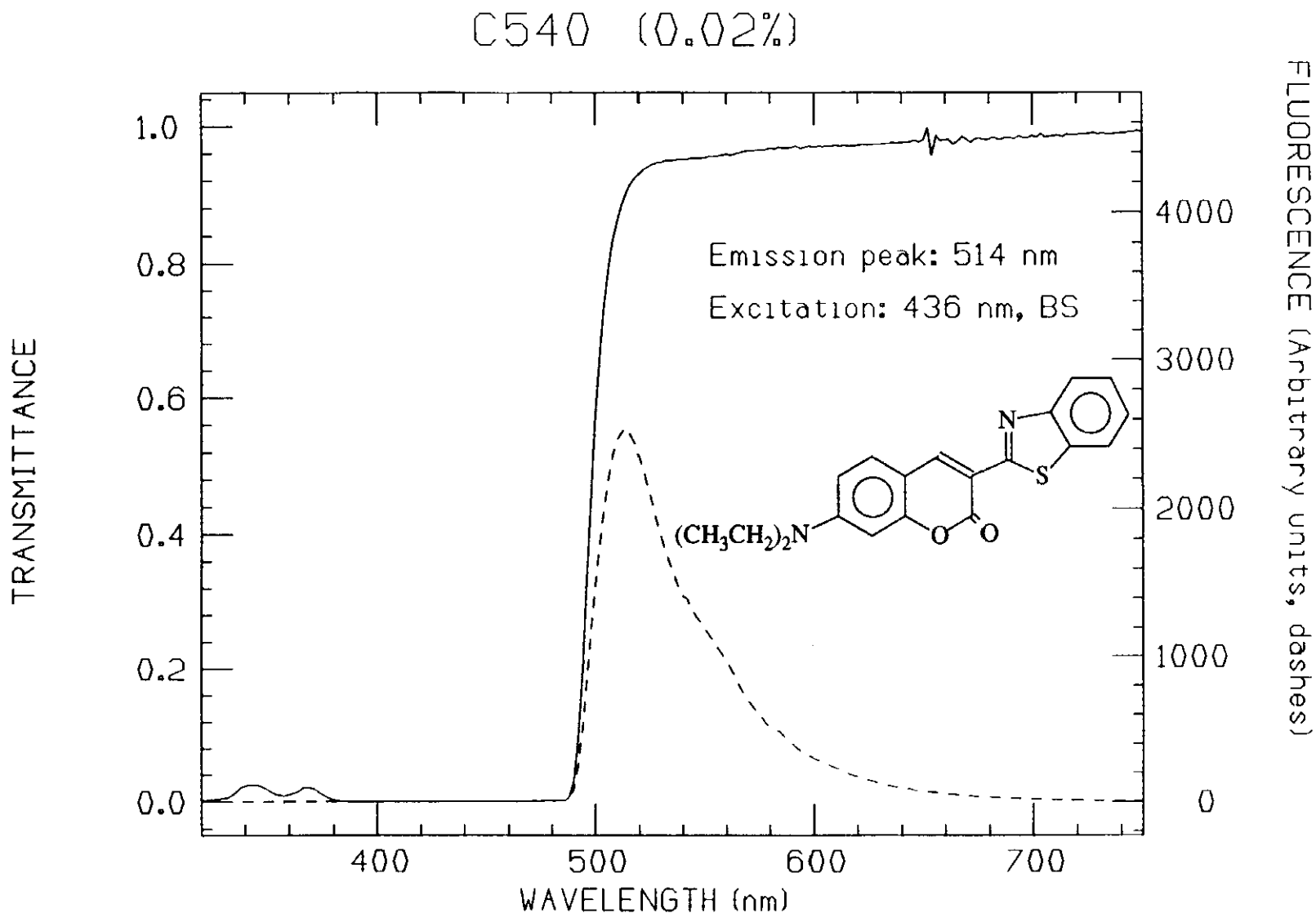

C521 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
4000
3000
2000
1000
0
Emission peak: 490 nm
Excitation: 436 nm, BS
O
C
CH3
N
O
O

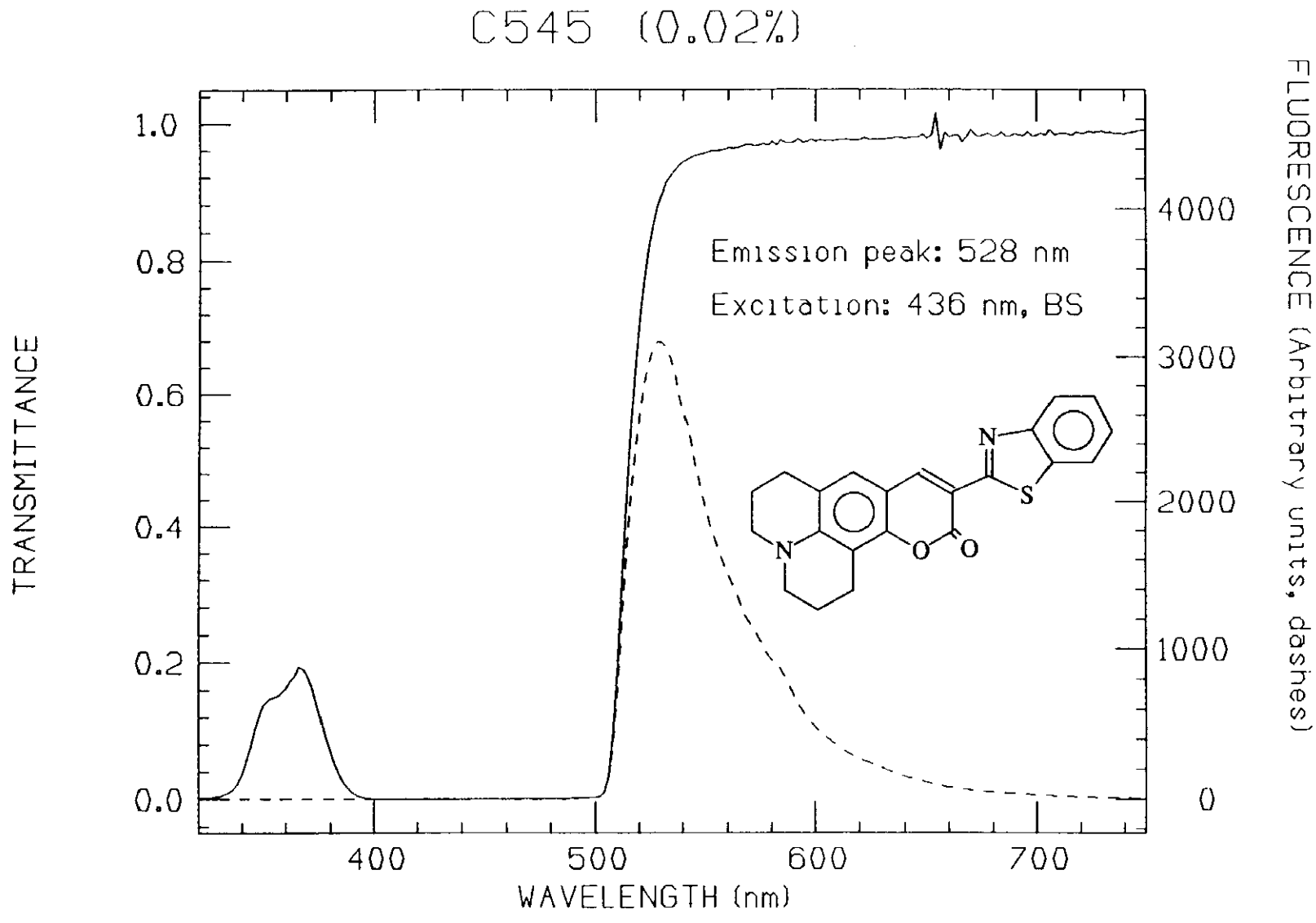

C522 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
4000
3000
2000
1000
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 472 nm
Excitation: 436 nm, BS
CF3
N
CH3
O
O

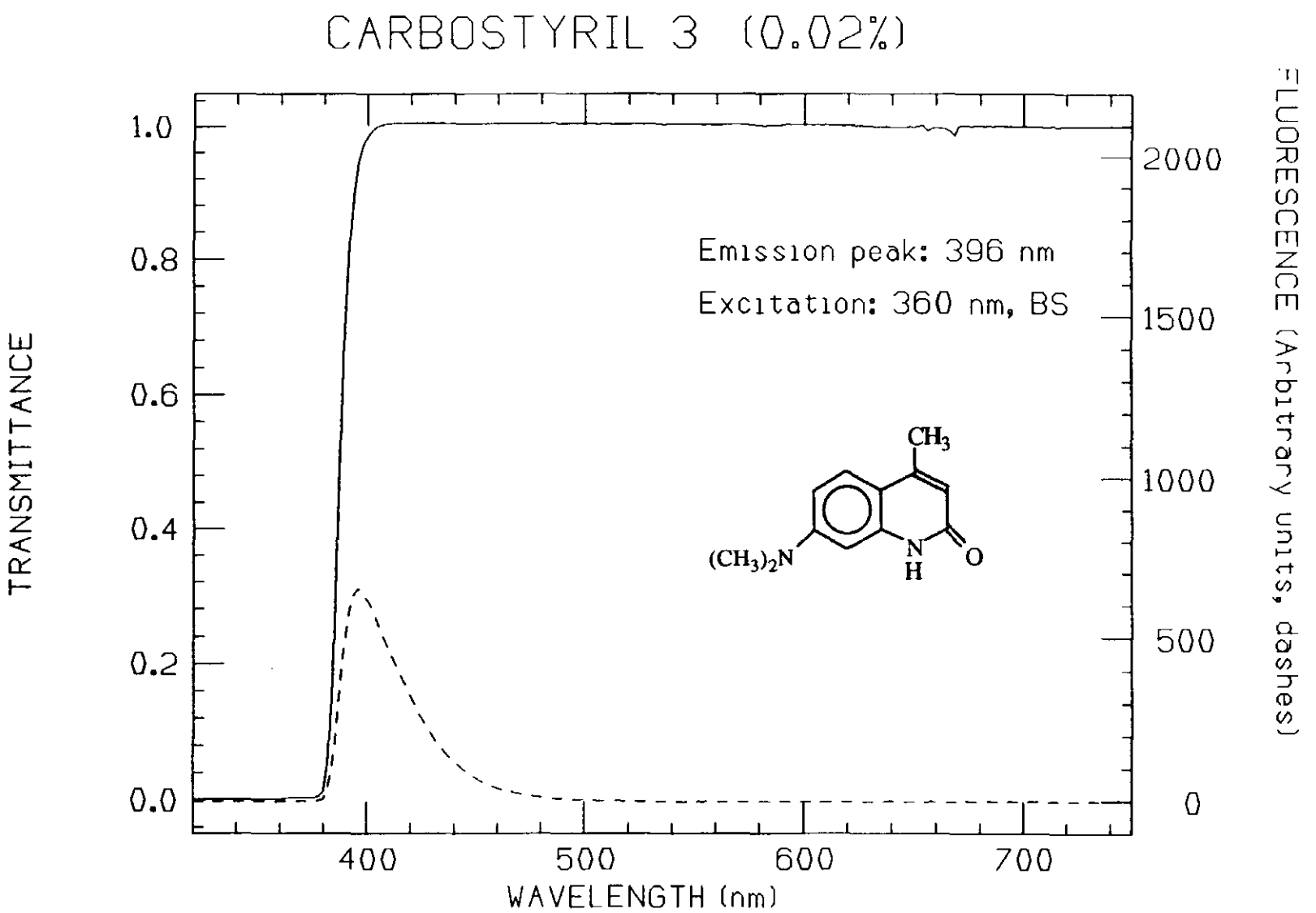

C523 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
4000
3000
2000
1000
0
Emission peak: 484 nm
Excitation: 436 nm, BS
CN
N
O
O

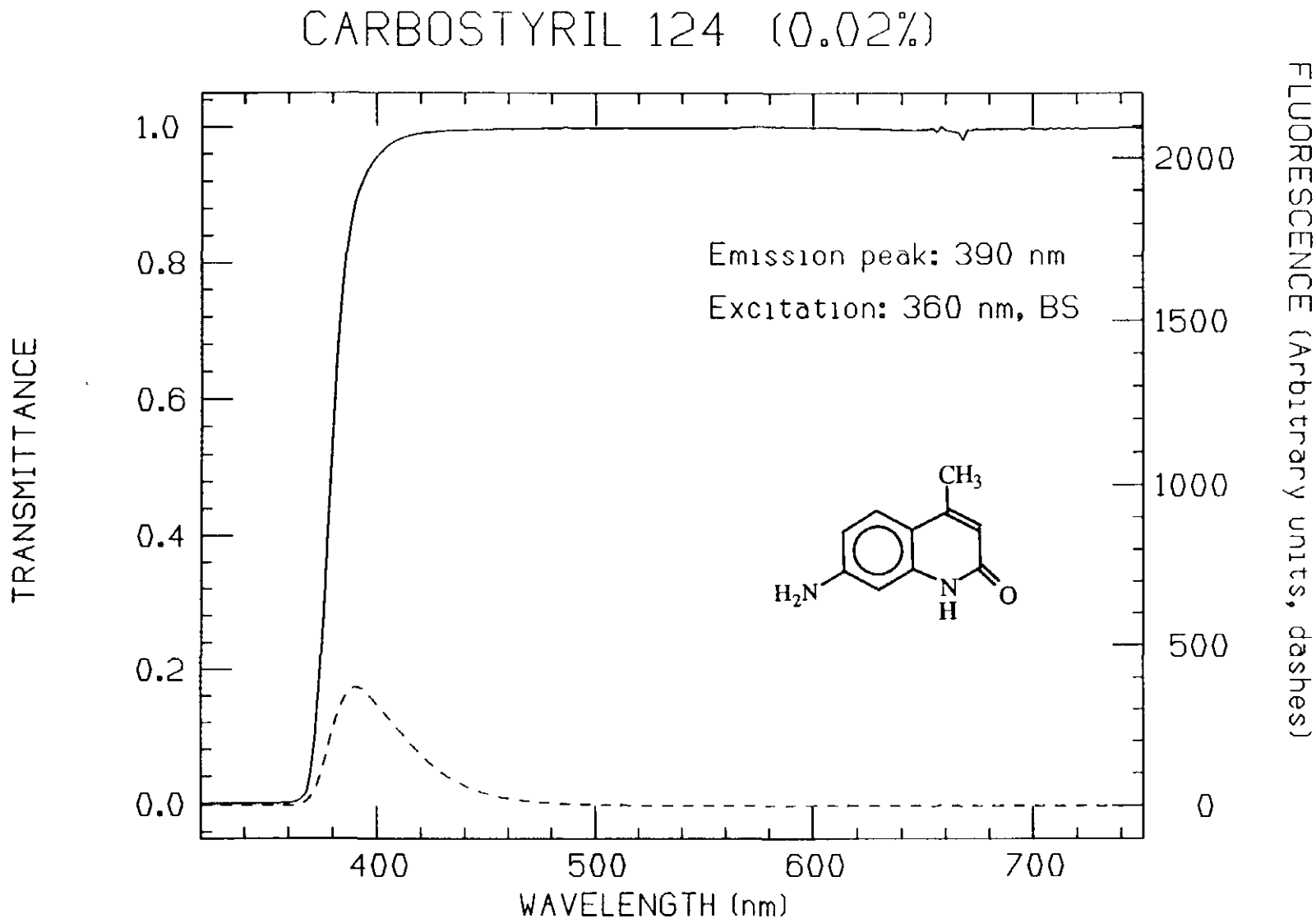

C525 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
4000
3000
2000
1000
0
Emission peak: 518 nm
Excitation: 436 nm, BS
N
O
N
O
O

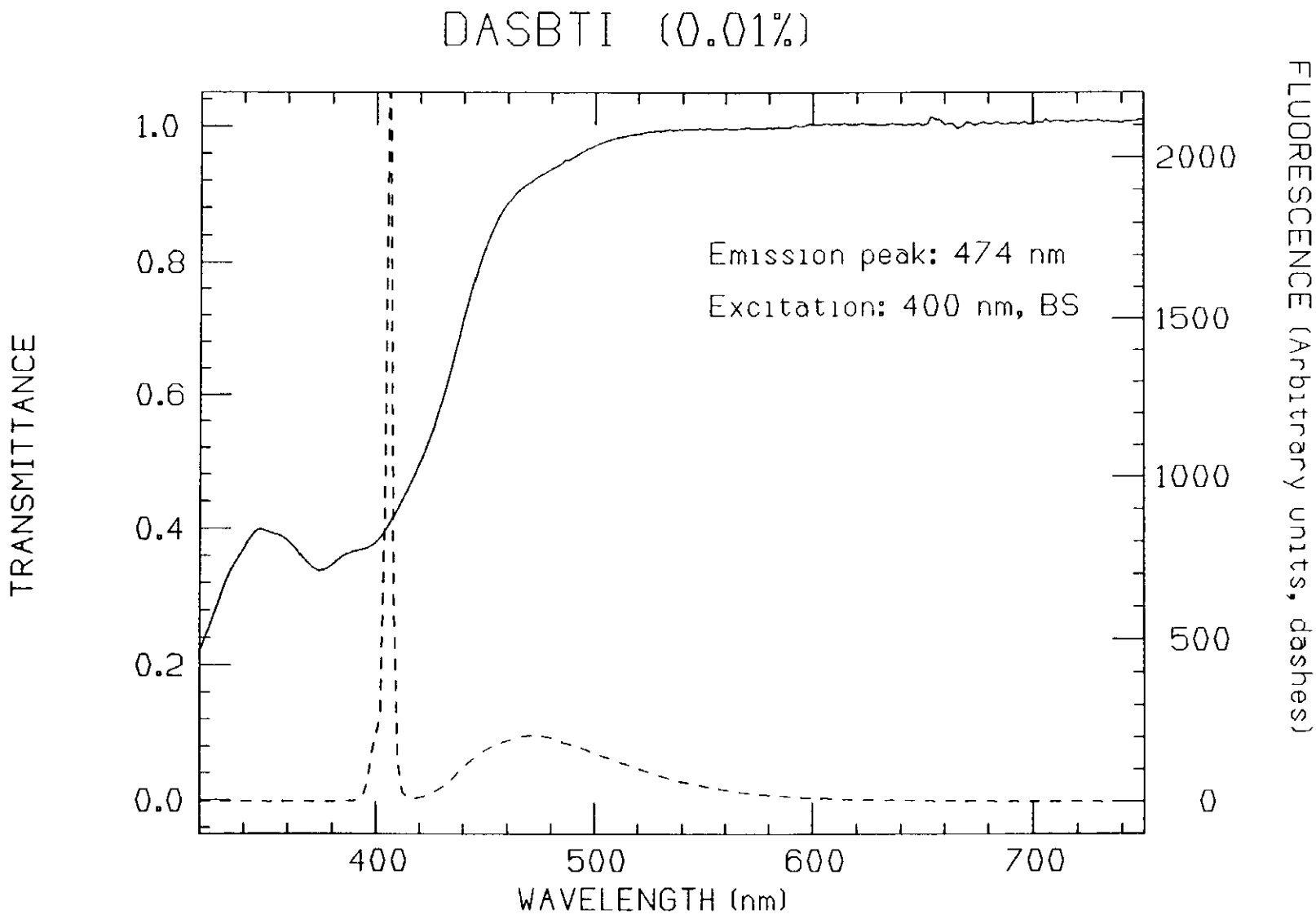

FLUORESCENCE (Arbitrary units, dashes)
4000
3000
2000
1000
0
C535 (0.02%)
Emission peak: 508 nm
Excitation: 436 nm, BS
N
H
N
O
O
(CH3CH2)2N
700
600
500
400
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
TRANSMITTANCE

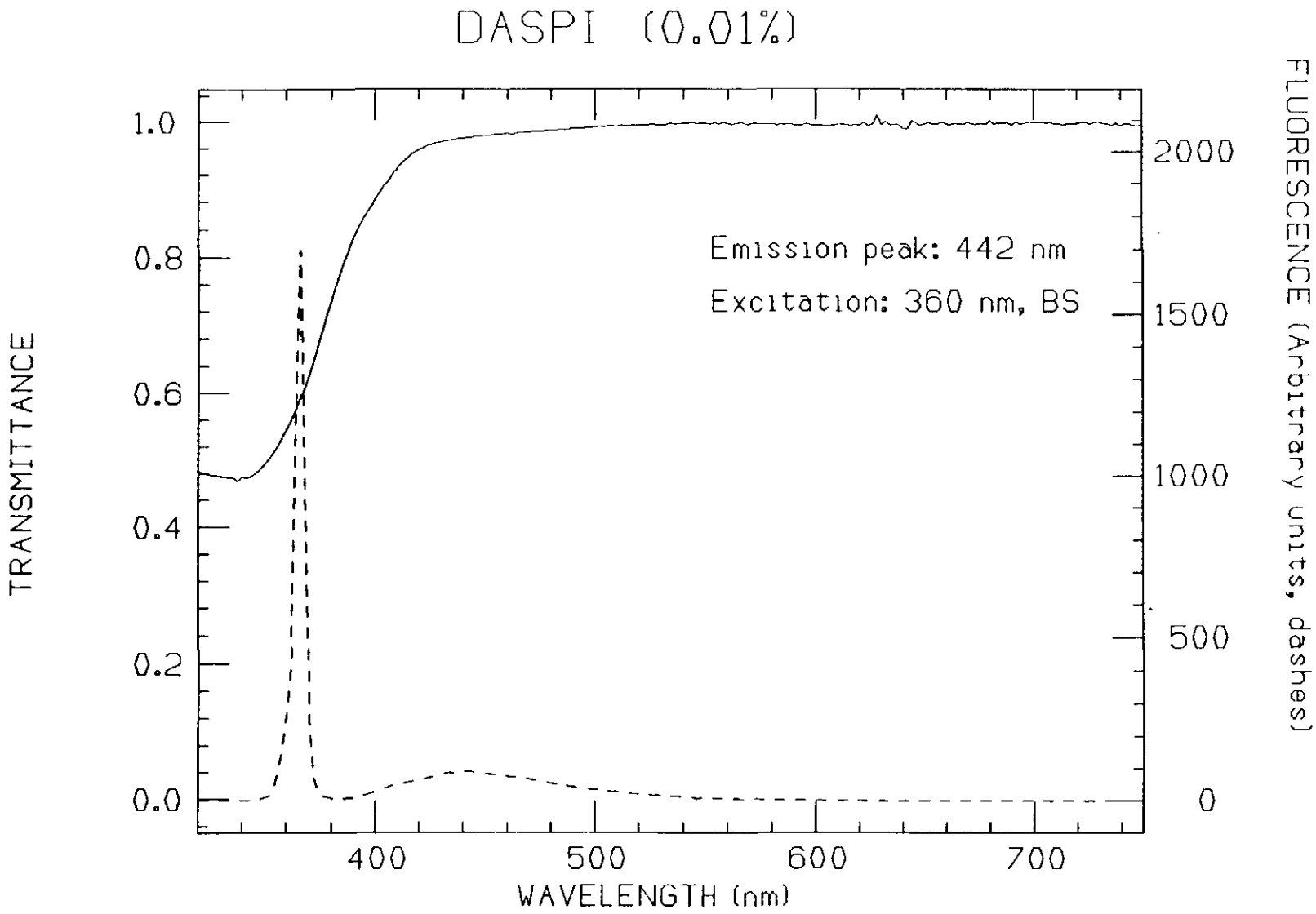

C540 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
4000
3000
2000
1000
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 514 nm
Excitation: 436 nm, BS
(CH3CH2)2N
N
S
O
O

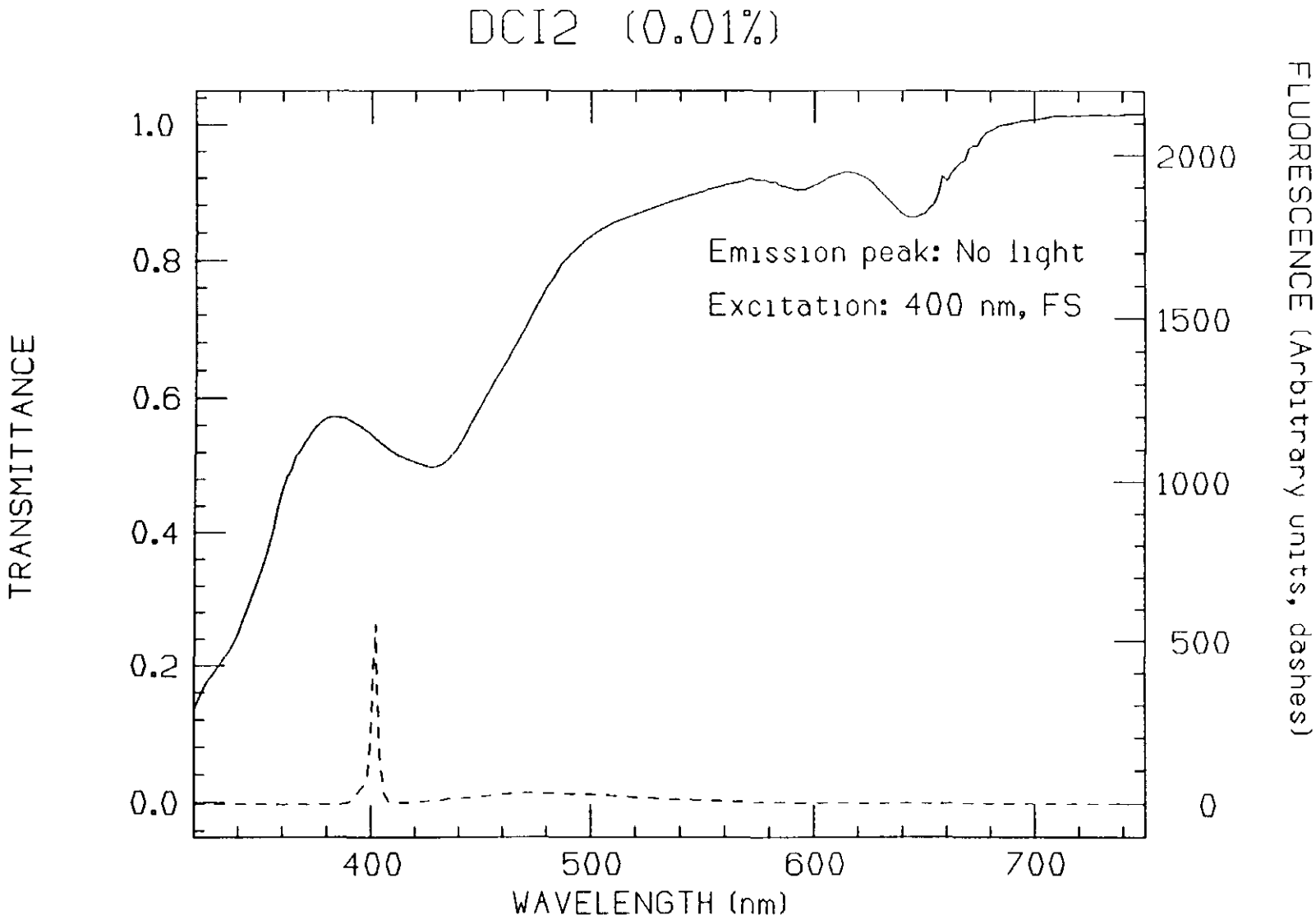

C545 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
4000
3000
2000
1000
0
Emission peak: 528 nm
Excitation: 436 nm, BS
N
S
N
O
O

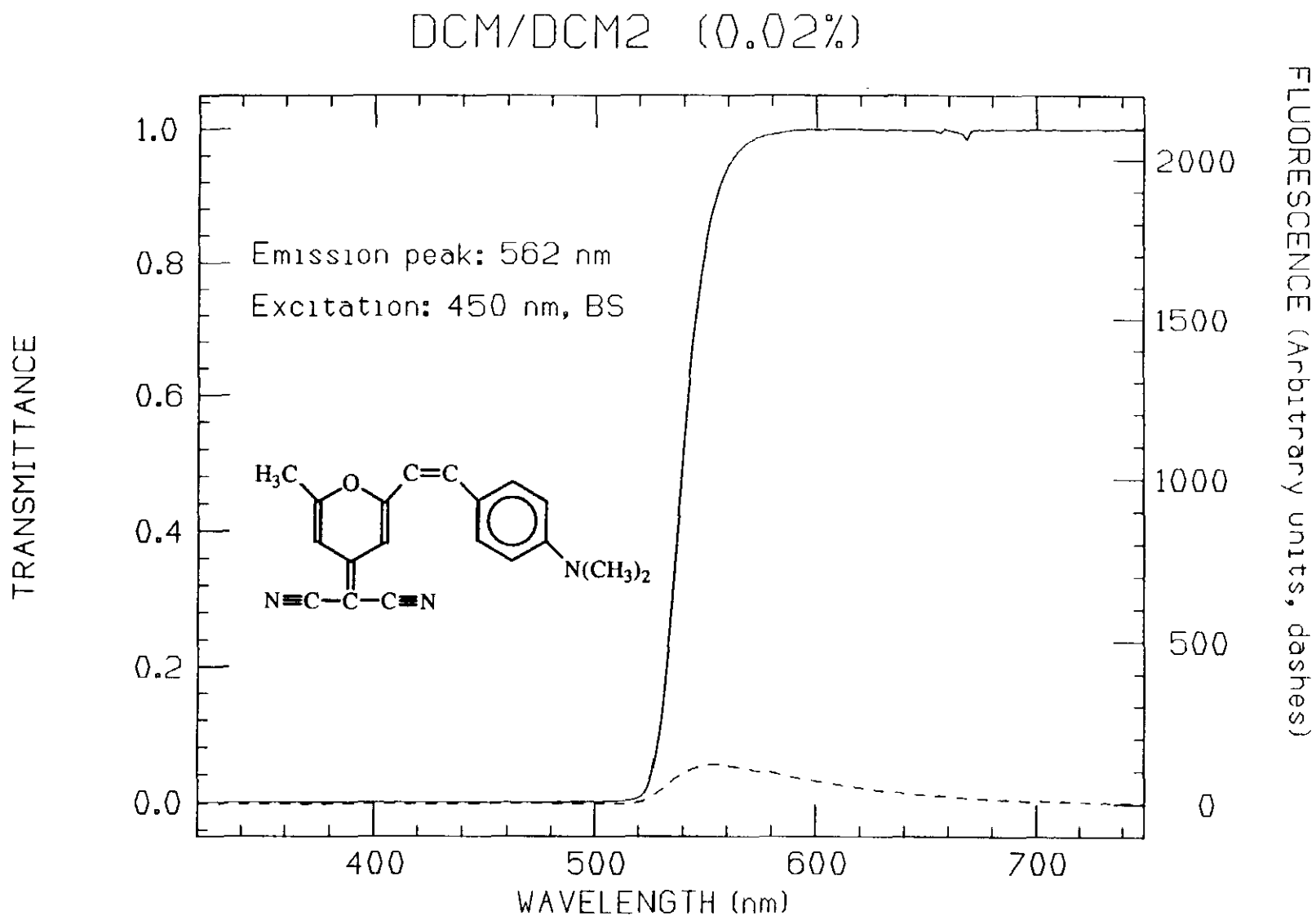

CARBOSTYRIL 3 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 396 nm
Excitation: 360 nm, BS
CH3
(CH3)2N
N
H
O

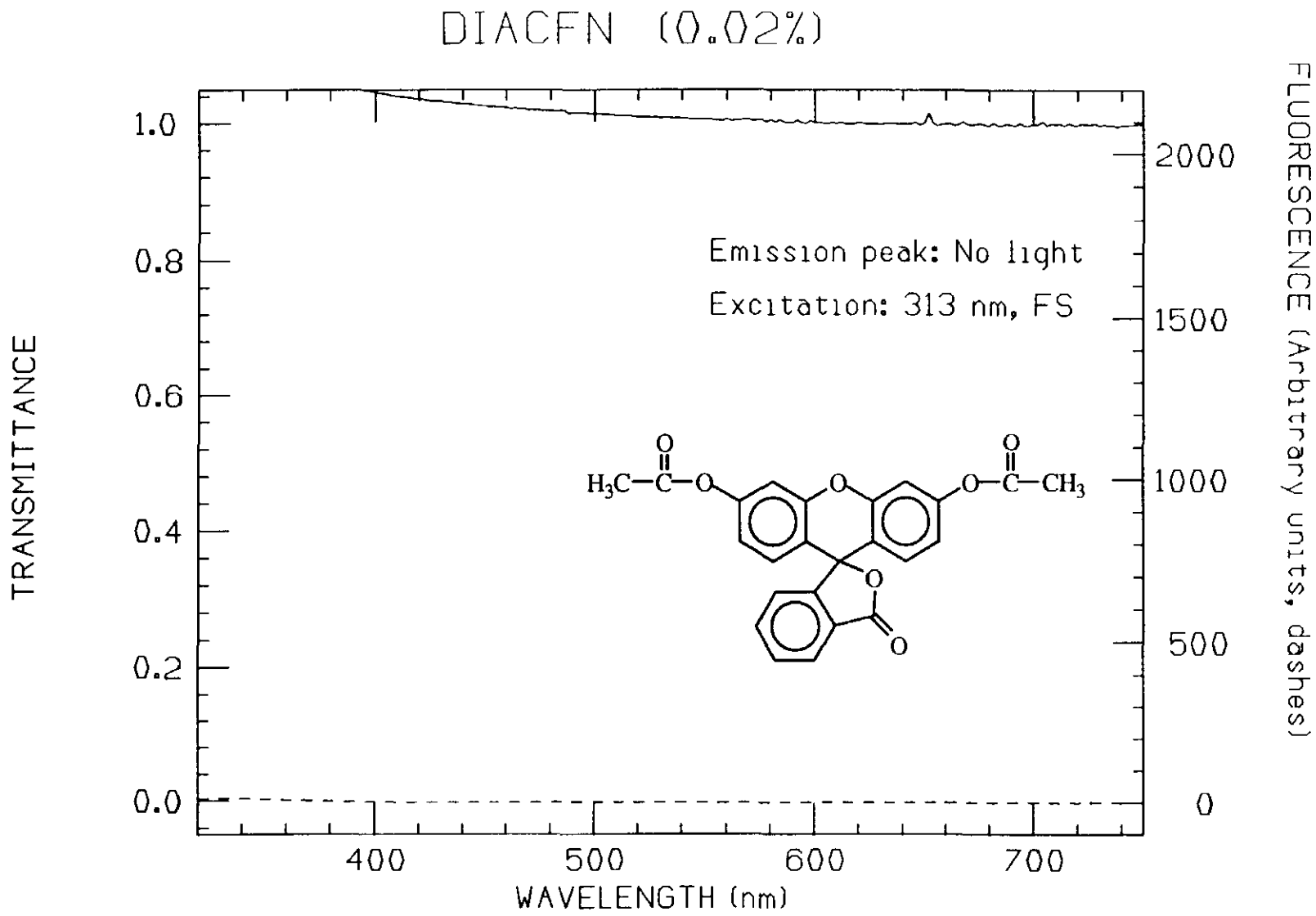

CARBOSTYRIL 124 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 390 nm
Excitation: 360 nm, BS
CH3
H2N
N
H
O

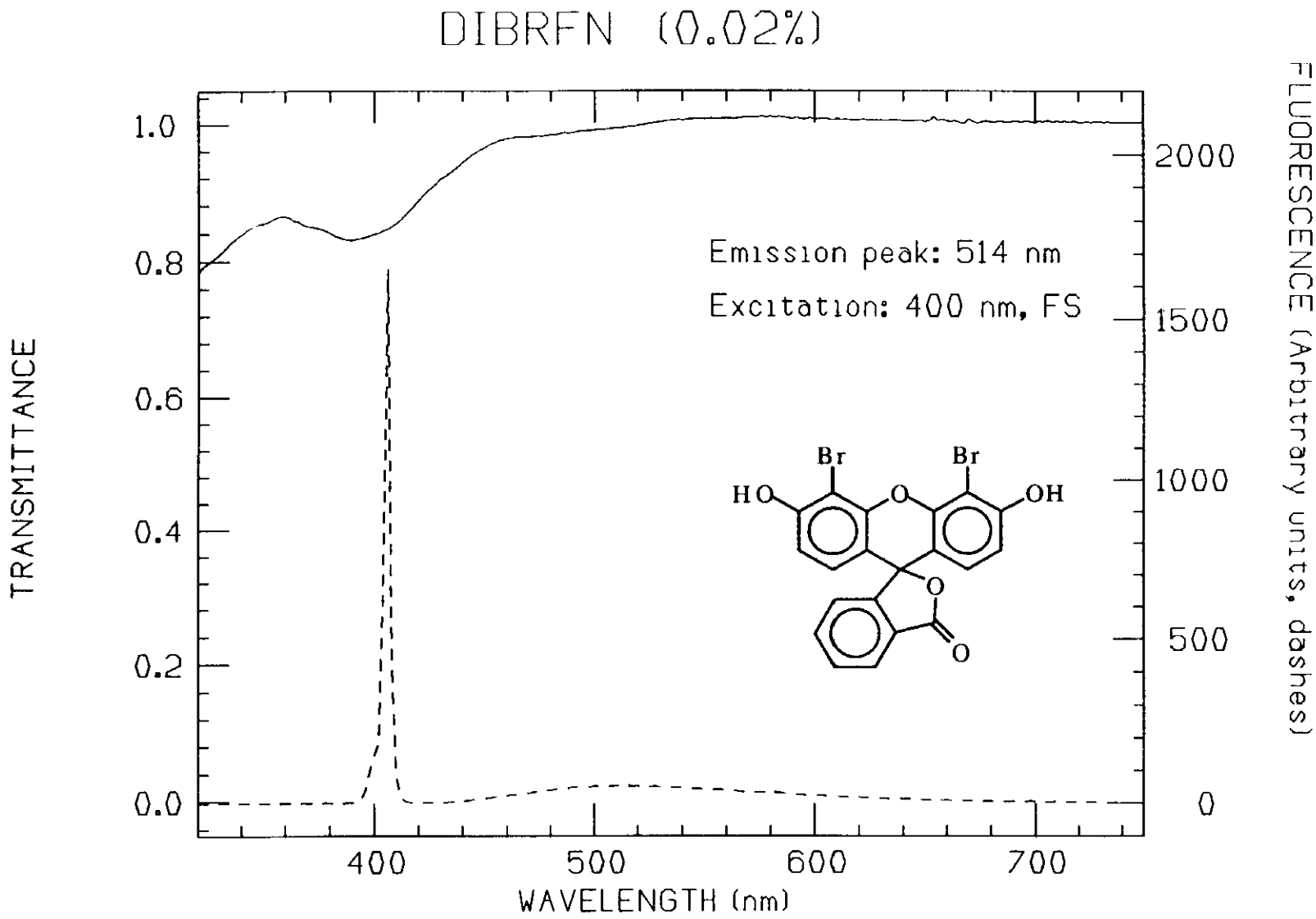

DASBTI (0.01%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 474 nm
Excitation: 400 nm, BS

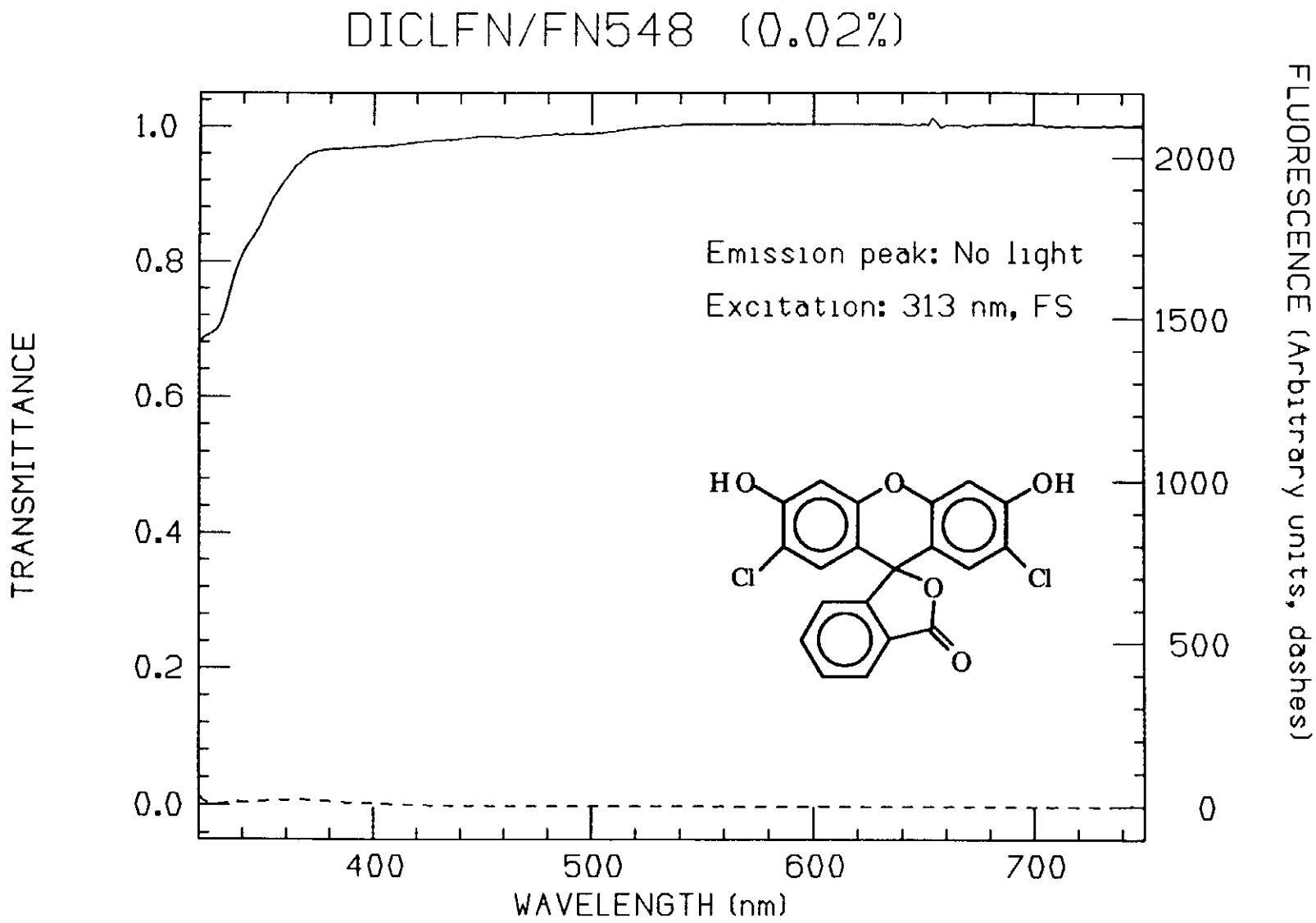

DASPI (0.01%)
TRANSMITTANCE
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 442 nm
Excitation: 360 nm, BS
FLUORESCENCE (Arbitrary units, dashes)
2000
1500
1000
500
0

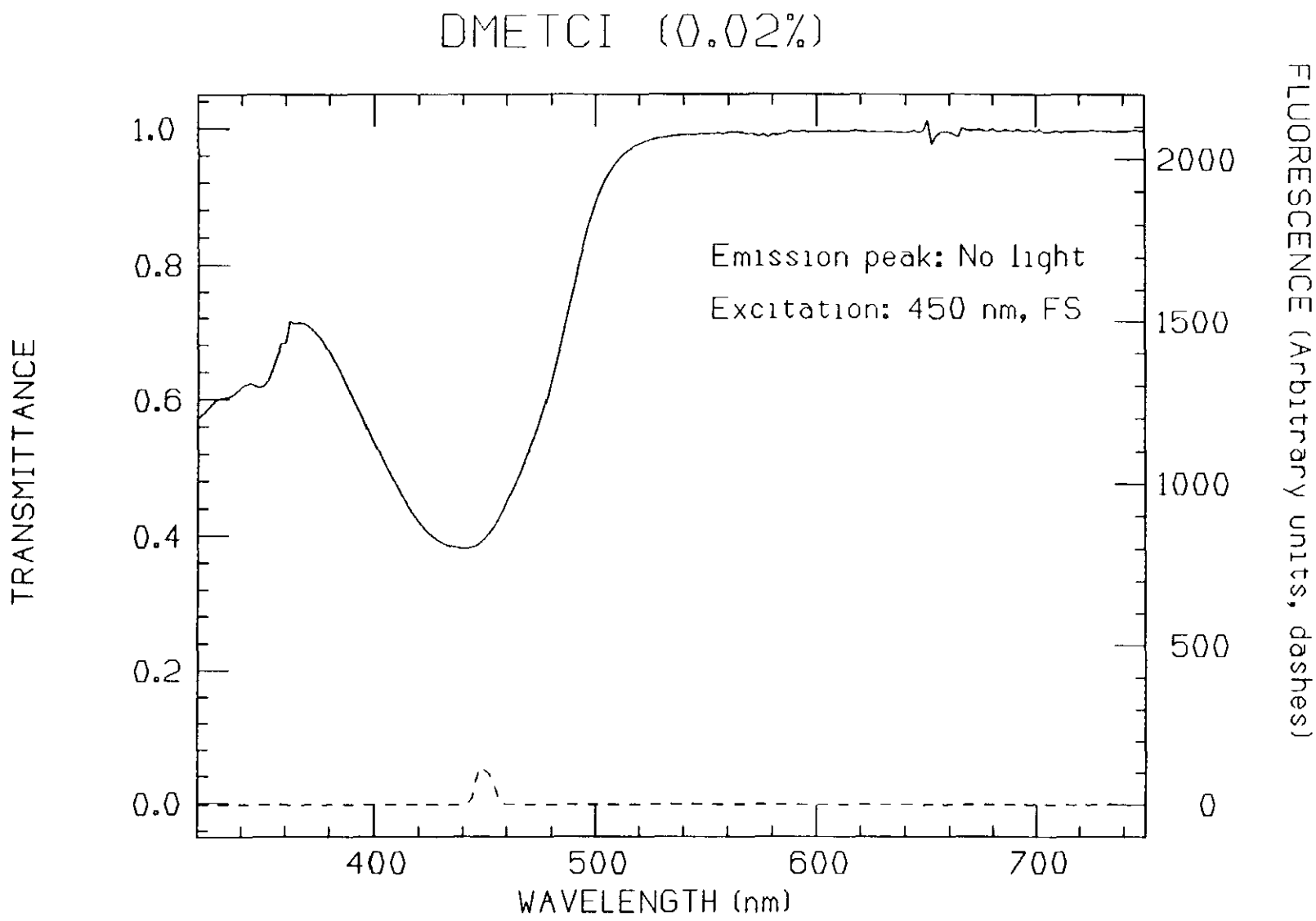

DCI2 (0.01%)
TRANSMITTANCE
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
WAVELENGTH (nm)
Emission peak: No light
Excitation: 400 nm, FS
2000
1500
1000
500
0
FLUORESCENCE (Arbitrary units, dashes)

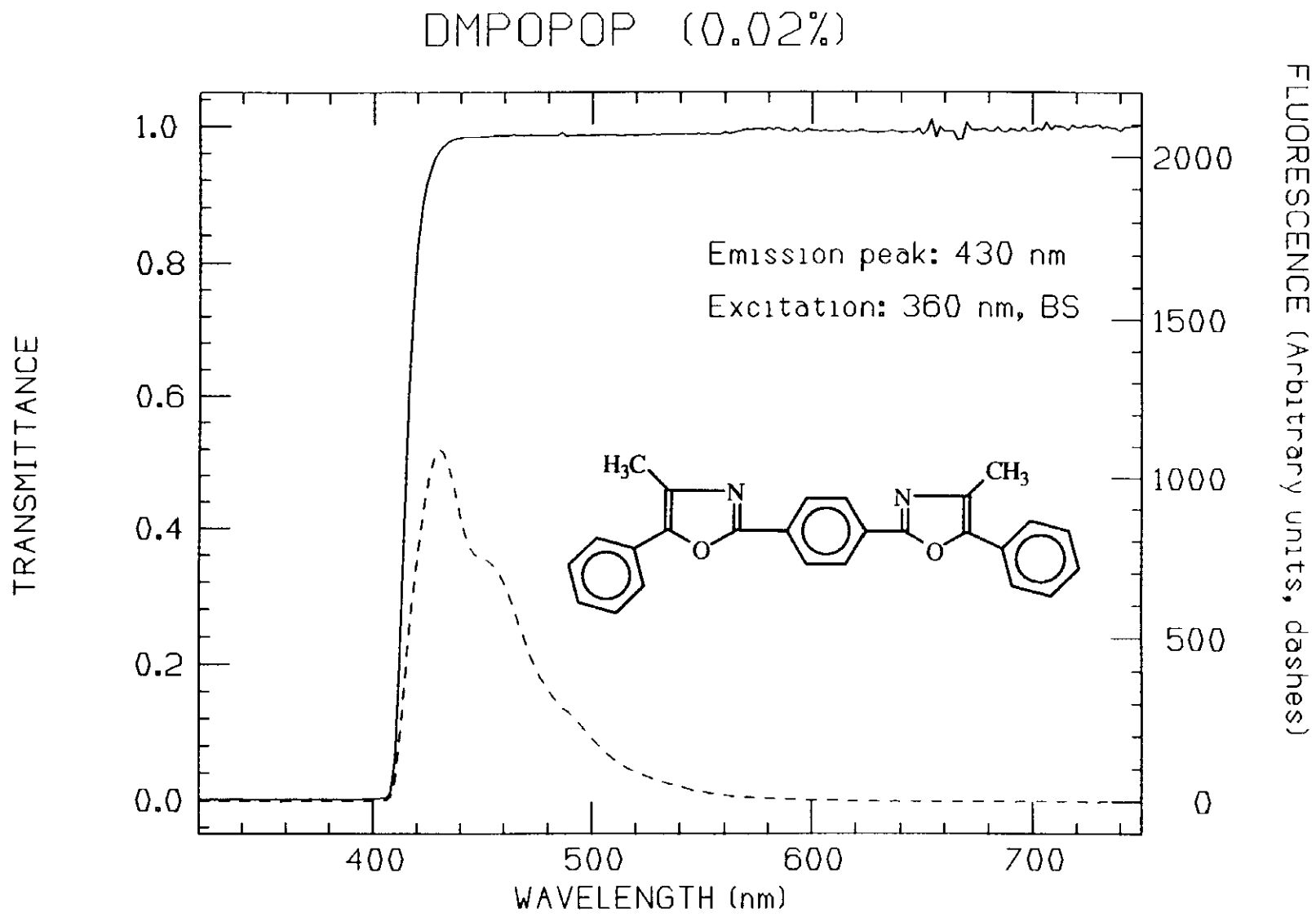

DCM/DCM2 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
Emission peak: 562 nm
Excitation: 450 nm, BS
H3C
O
C=C
N(CH3)2
N≡C–C–C≡N

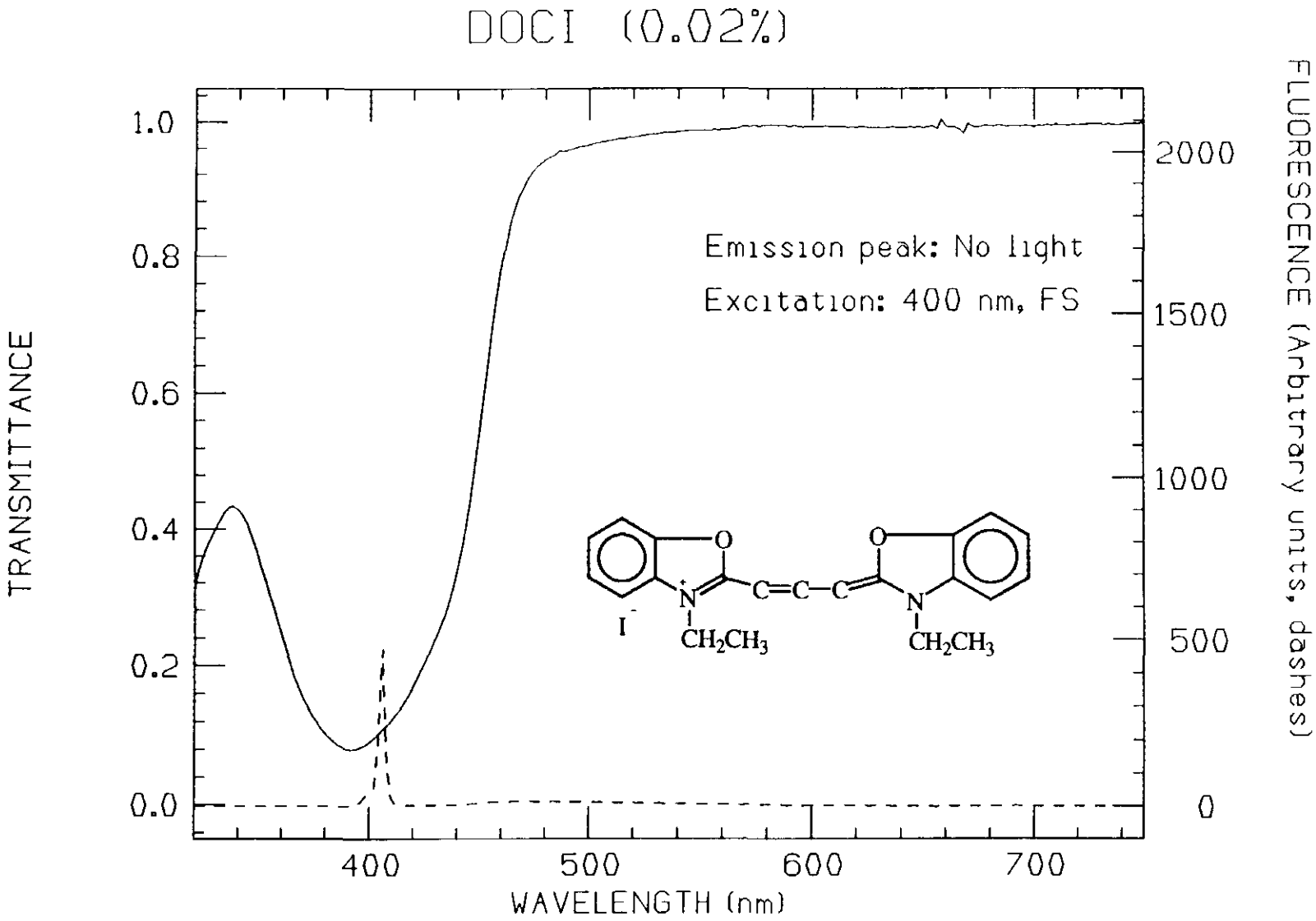

DIACFN (0.02%)
TRANSMITTANCE
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
WAVELENGTH (nm)
FLUORESCENCE (Arbitrary units, dashes)
2000
1500
1000
500
0
Emission peak: No light
Excitation: 313 nm, FS

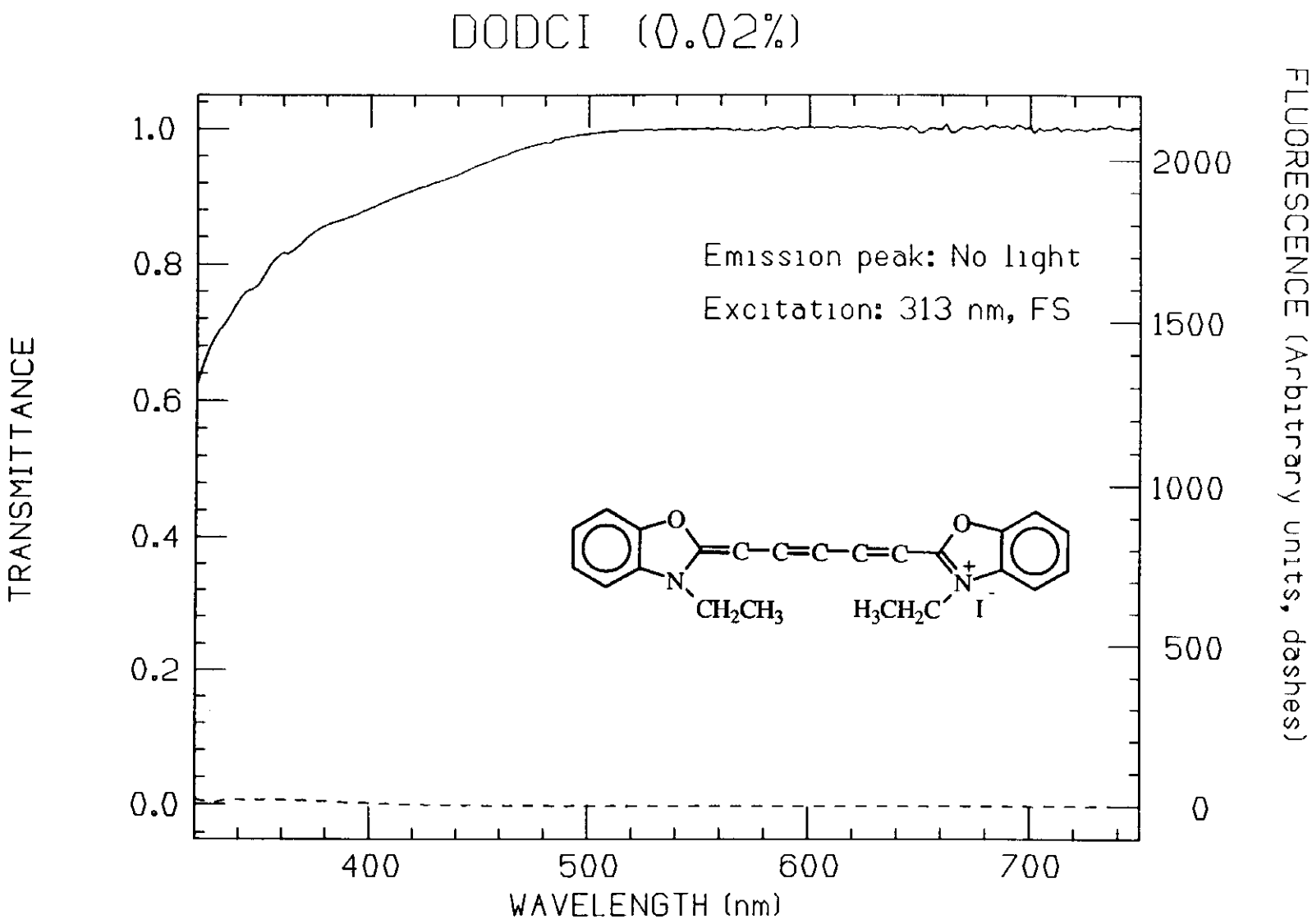

DIBRFN (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
Emission peak: 514 nm
Excitation: 400 nm, FS
Br
Br
HO
OH
O
O
O

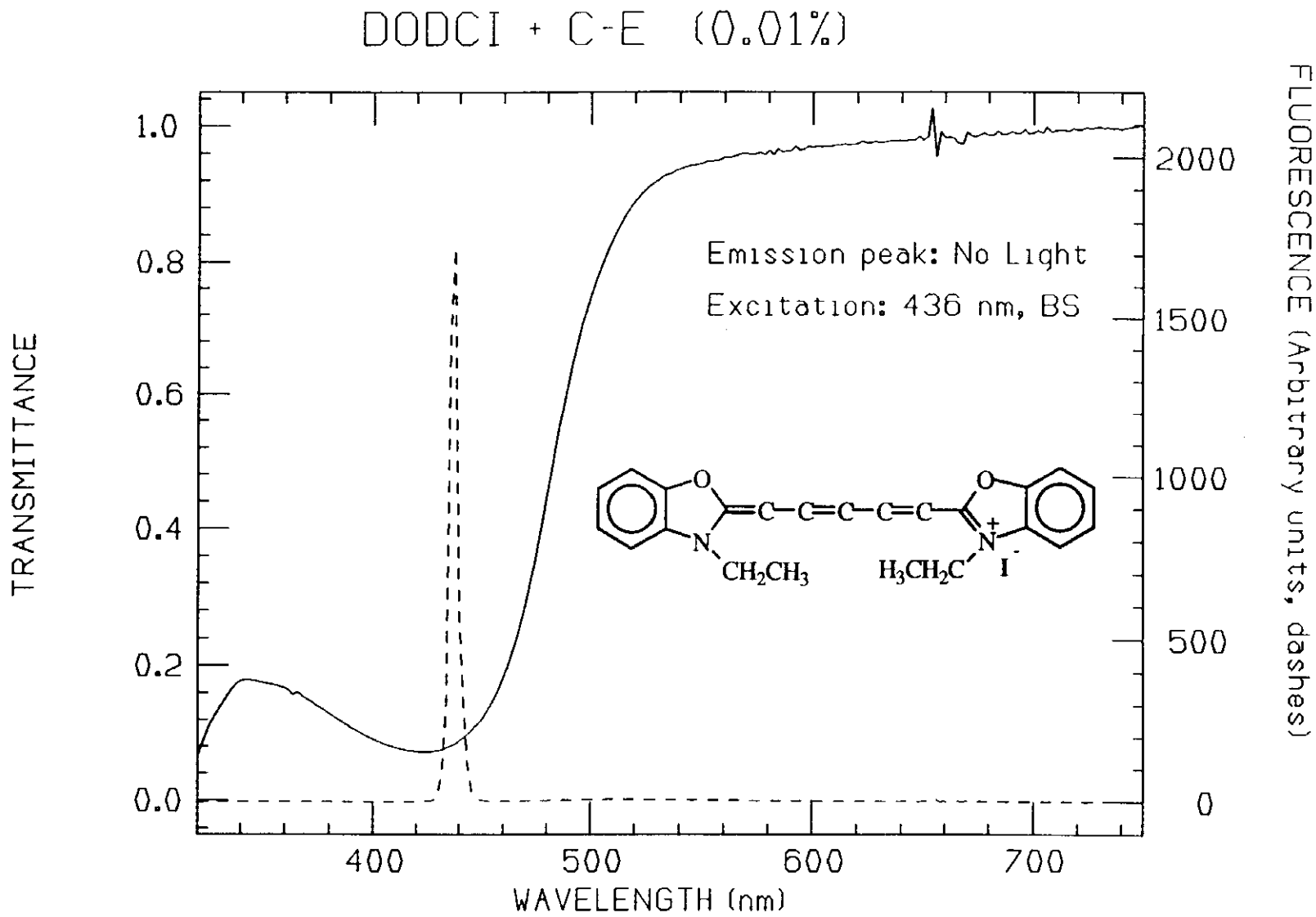

DICLFN/FN548 (0.02%)
TRANSMITTANCE
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
WAVELENGTH (nm)
FLUORESCENCE (Arbitrary units, dashes)
2000
1500
1000
500
0
Emission peak: No light
Excitation: 313 nm, FS
HO
O
OH
Cl
Cl
O
O

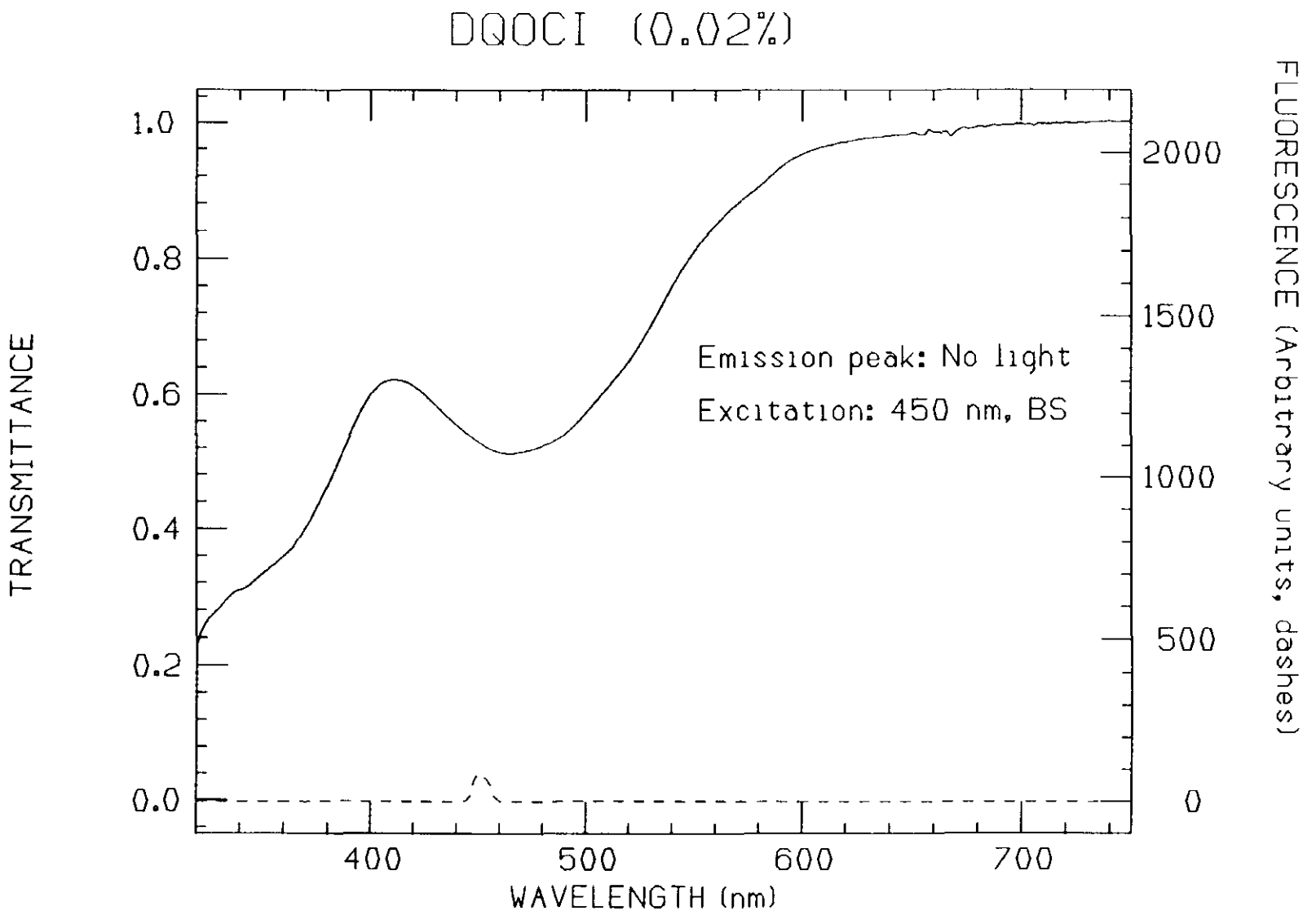

DMETCI (0.02%)
TRANSMITTANCE
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
WAVELENGTH (nm)
Emission peak: No light
Excitation: 450 nm, FS
FLUORESCENCE (Arbitrary units, dashes)
2000
1500
1000
500
0

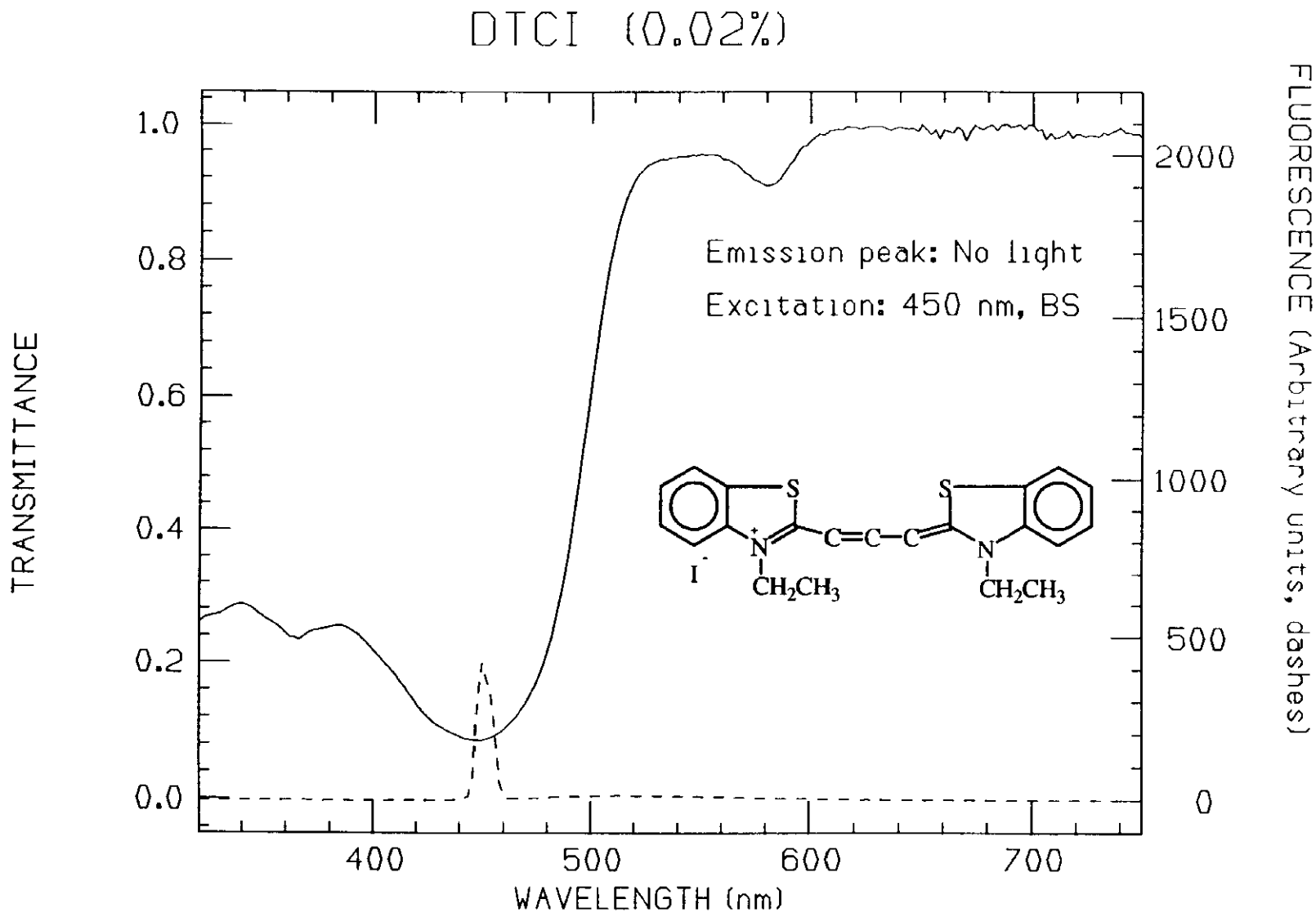

DMPOPOP (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
Emission peak: 430 nm
Excitation: 360 nm, BS
H3C
CH3
N
N
O
O

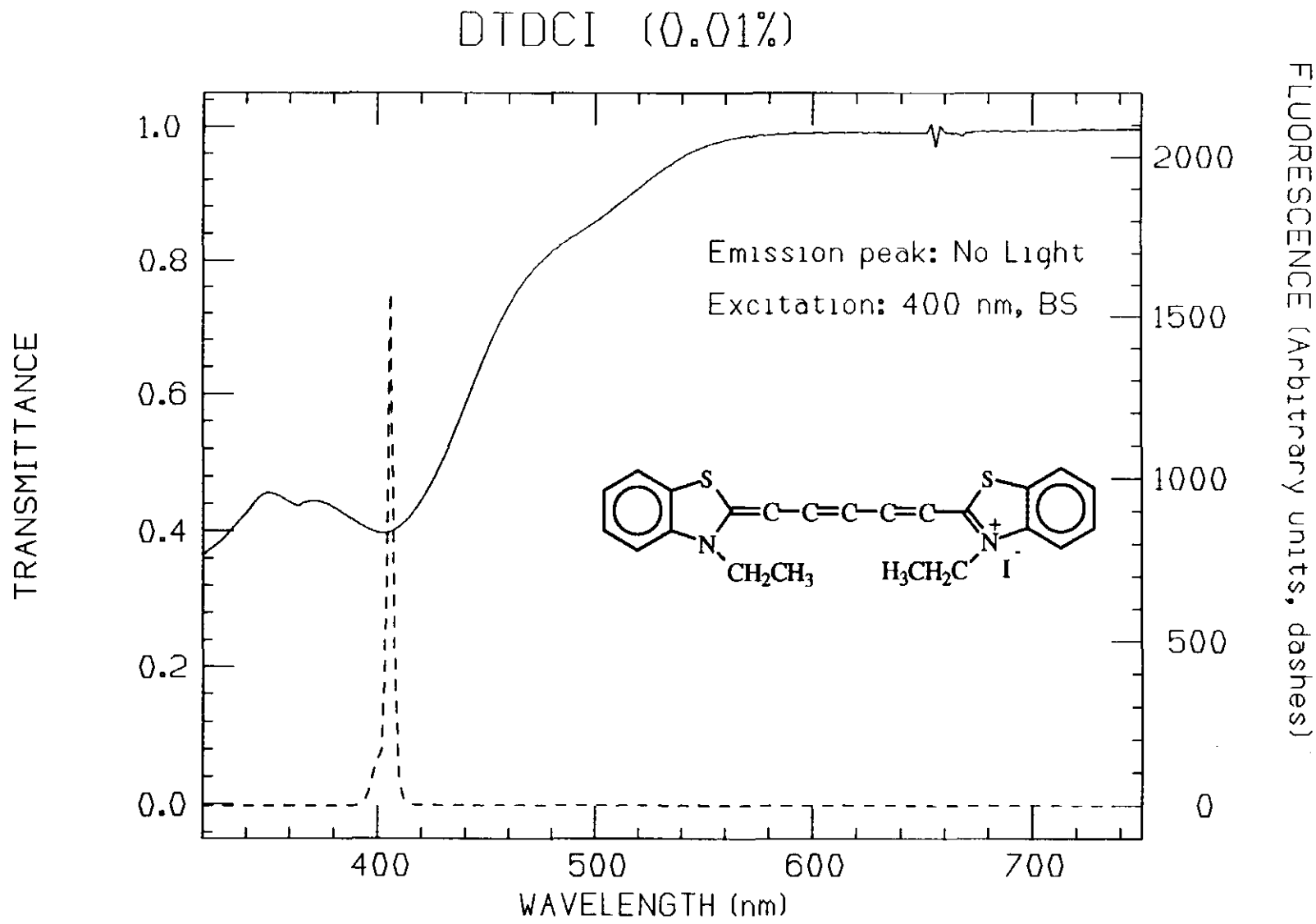

DOCI (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: No light
Excitation: 400 nm, FS
O
O
N
C=C-C
N
I⁻
CH2CH3
CH2CH3

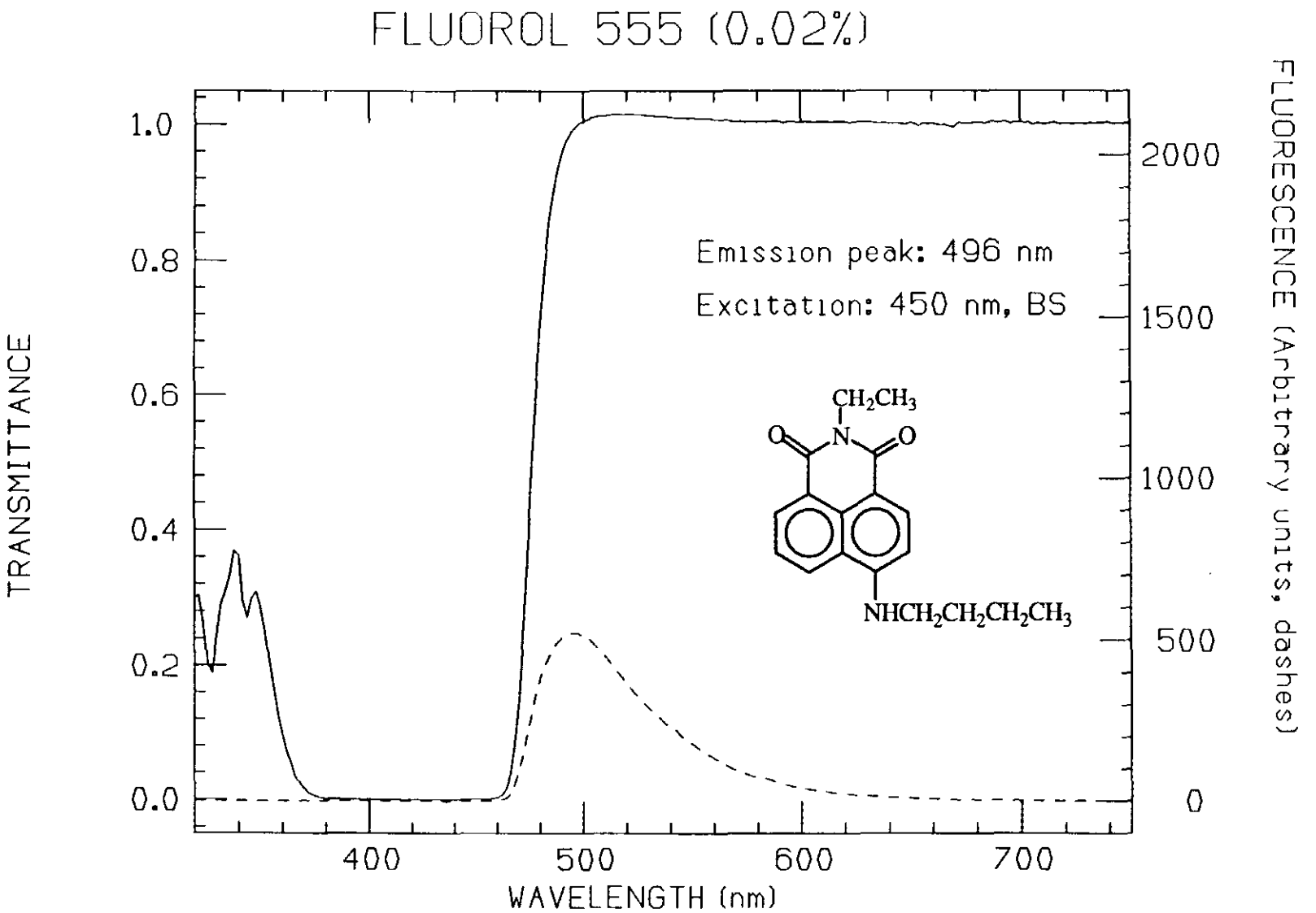

DODCI (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: No light
Excitation: 313 nm, FS
CH2CH3
H3CH2C
I

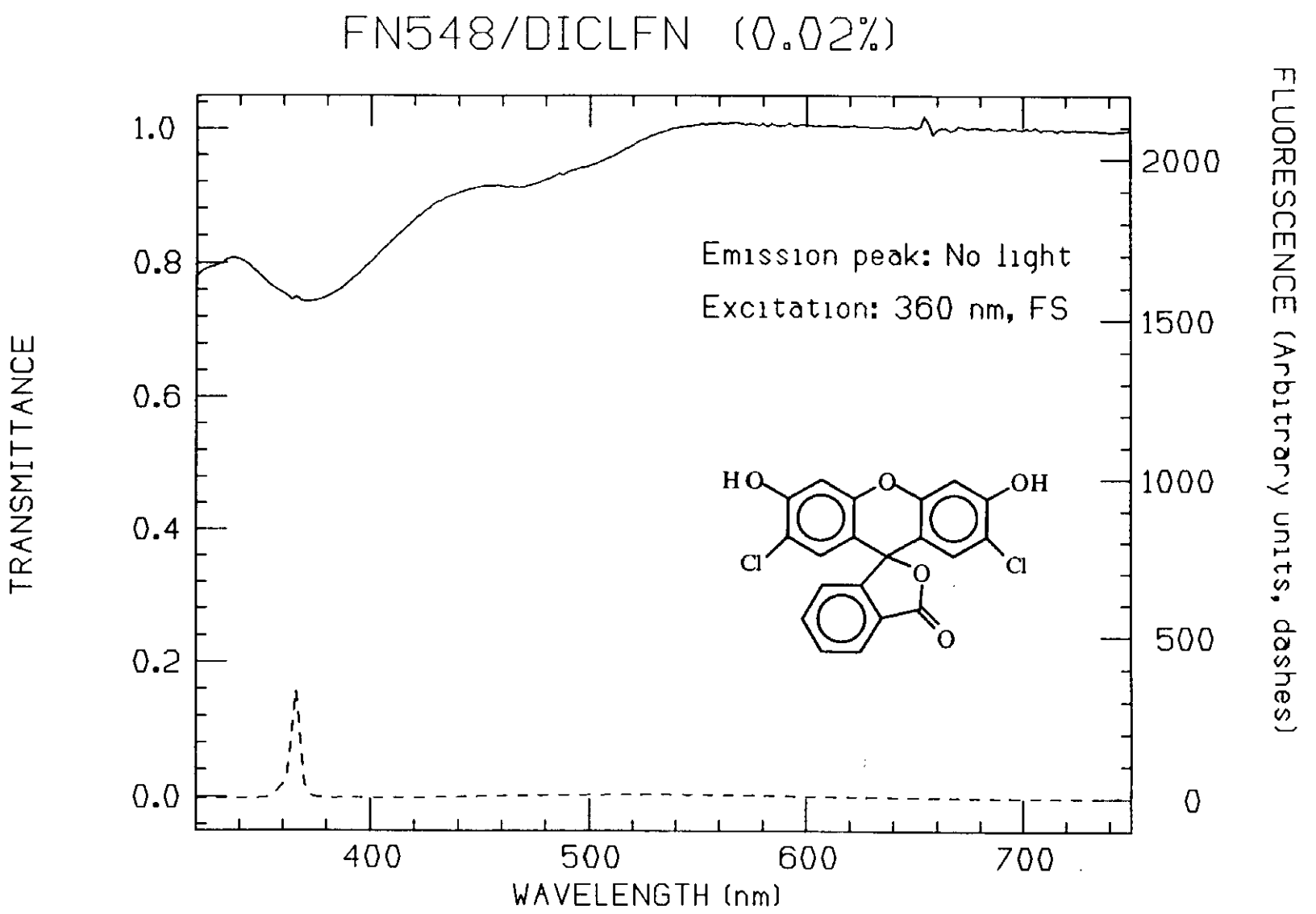

DODCI + C-E (0.01%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: No Light
Excitation: 436 nm, BS
O
C-C=C-C=C-C
O
N
CH2CH3
H3CH2C
N+
I-

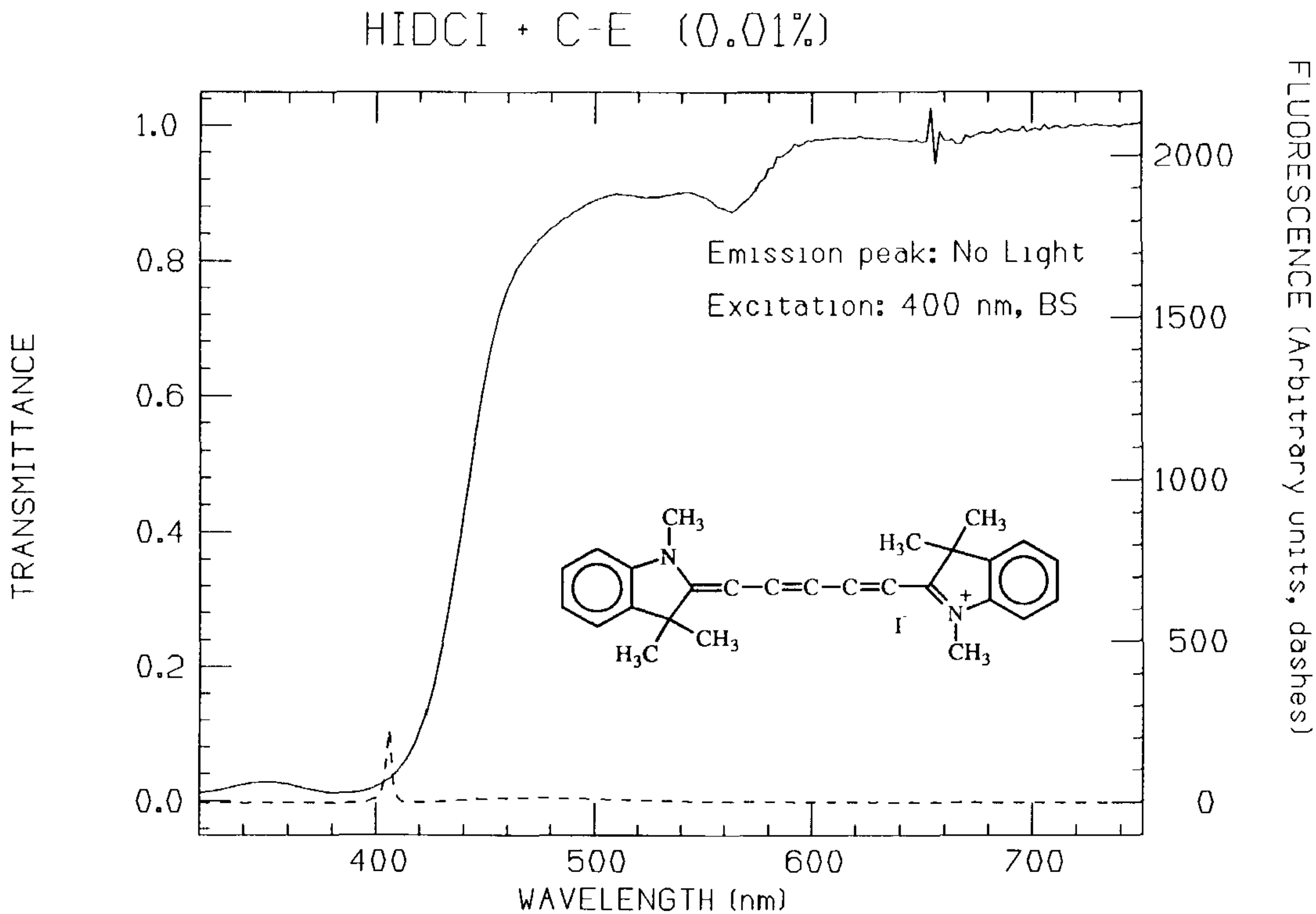

DQOCI (0.02%)
TRANSMITTANCE
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
WAVELENGTH (nm)
Emission peak: No light
Excitation: 450 nm, BS
FLUORESCENCE (Arbitrary units, dashes)
2000
1500
1000
500
0

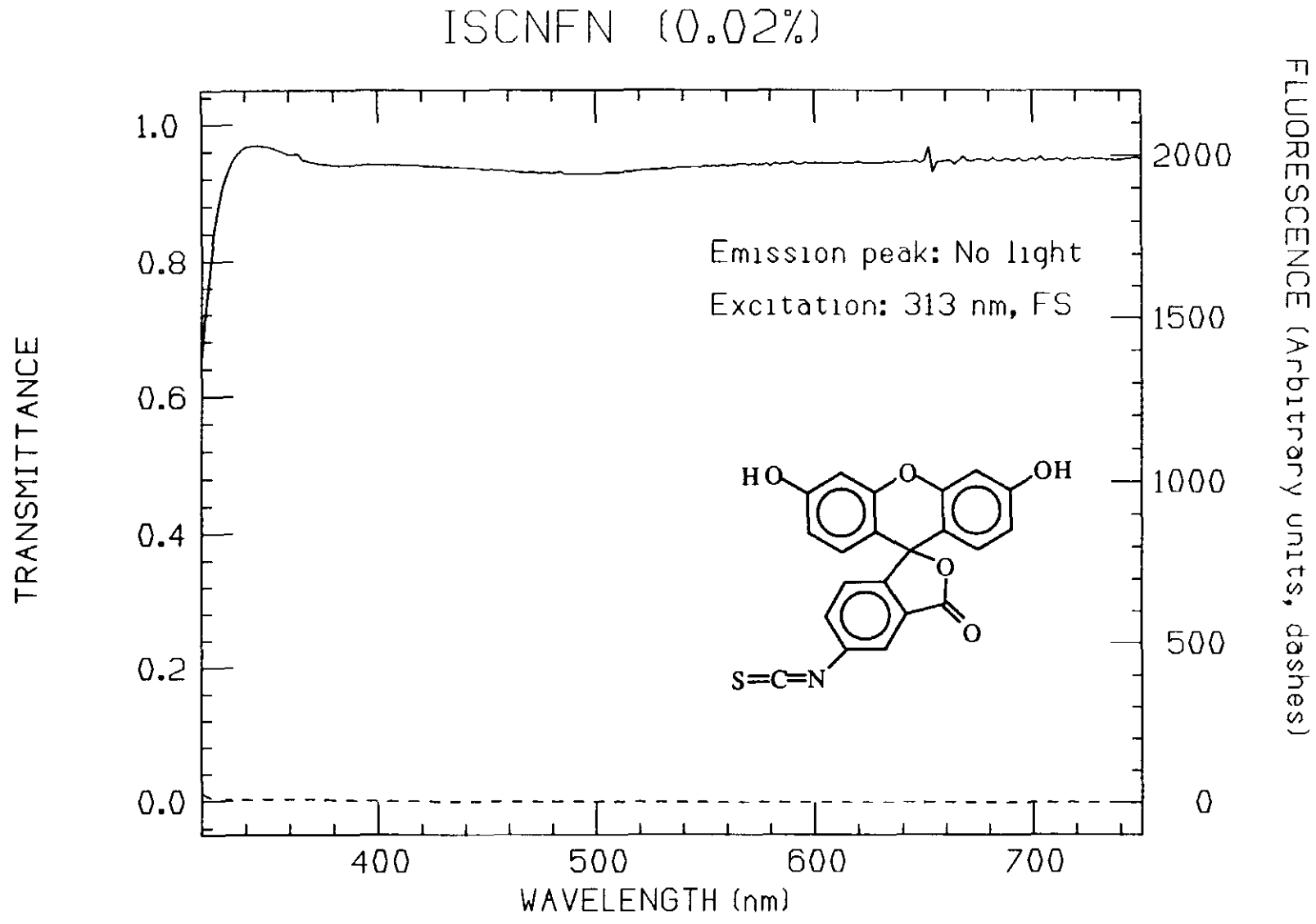

DTCI (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
Emission peak: No light
Excitation: 450 nm, BS
S
S
N
C=C-C
N
I
CH2CH3
CH2CH3


DTDCI (0.01%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: No Light
Excitation: 400 nm, BS
S
N
CH2CH3
H3CH2C
I-

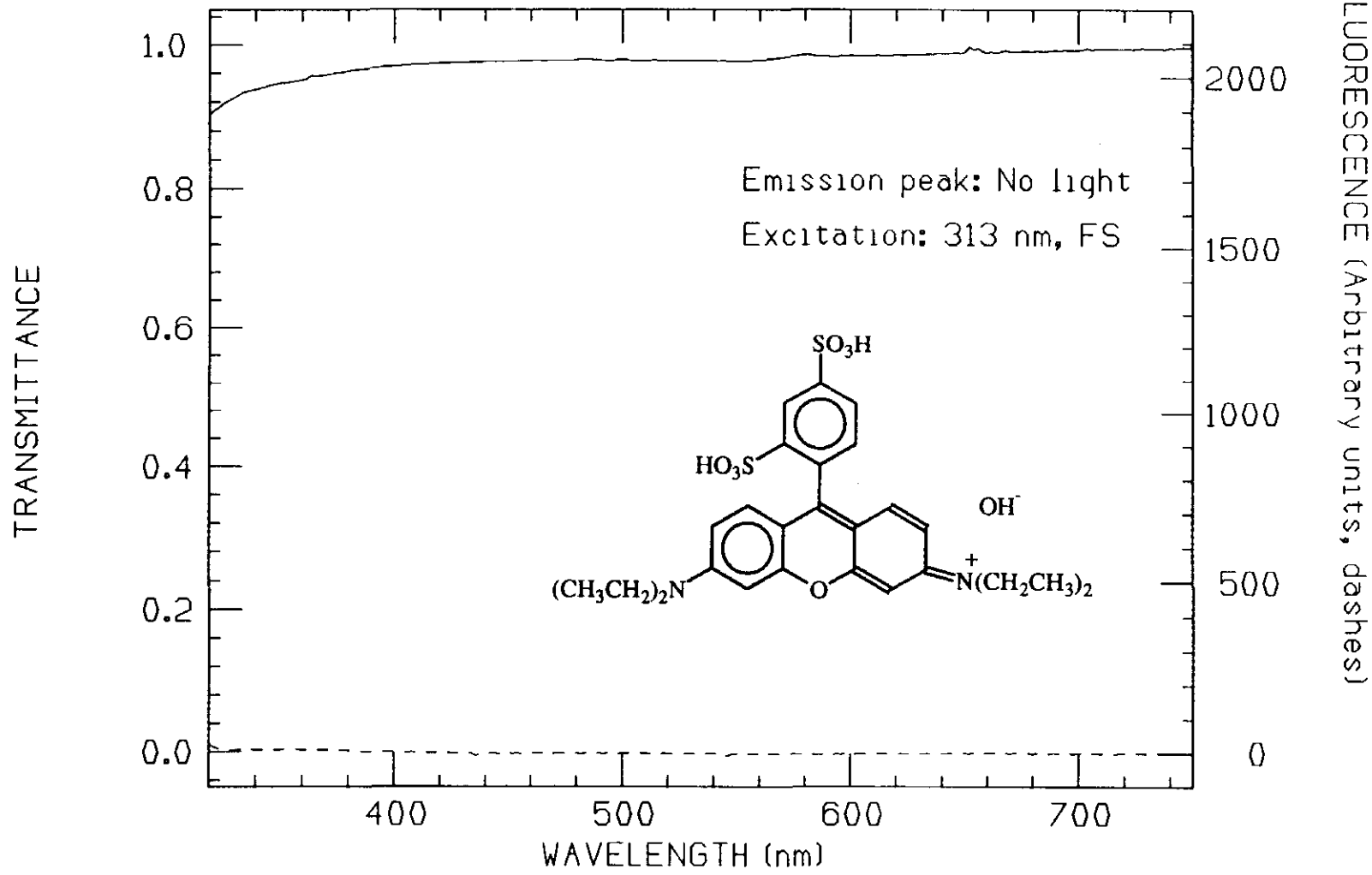

FLUOROL 555 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 496 nm
Excitation: 450 nm, BS
CH2CH3
N
O
O
NHCH2CH2CH2CH3

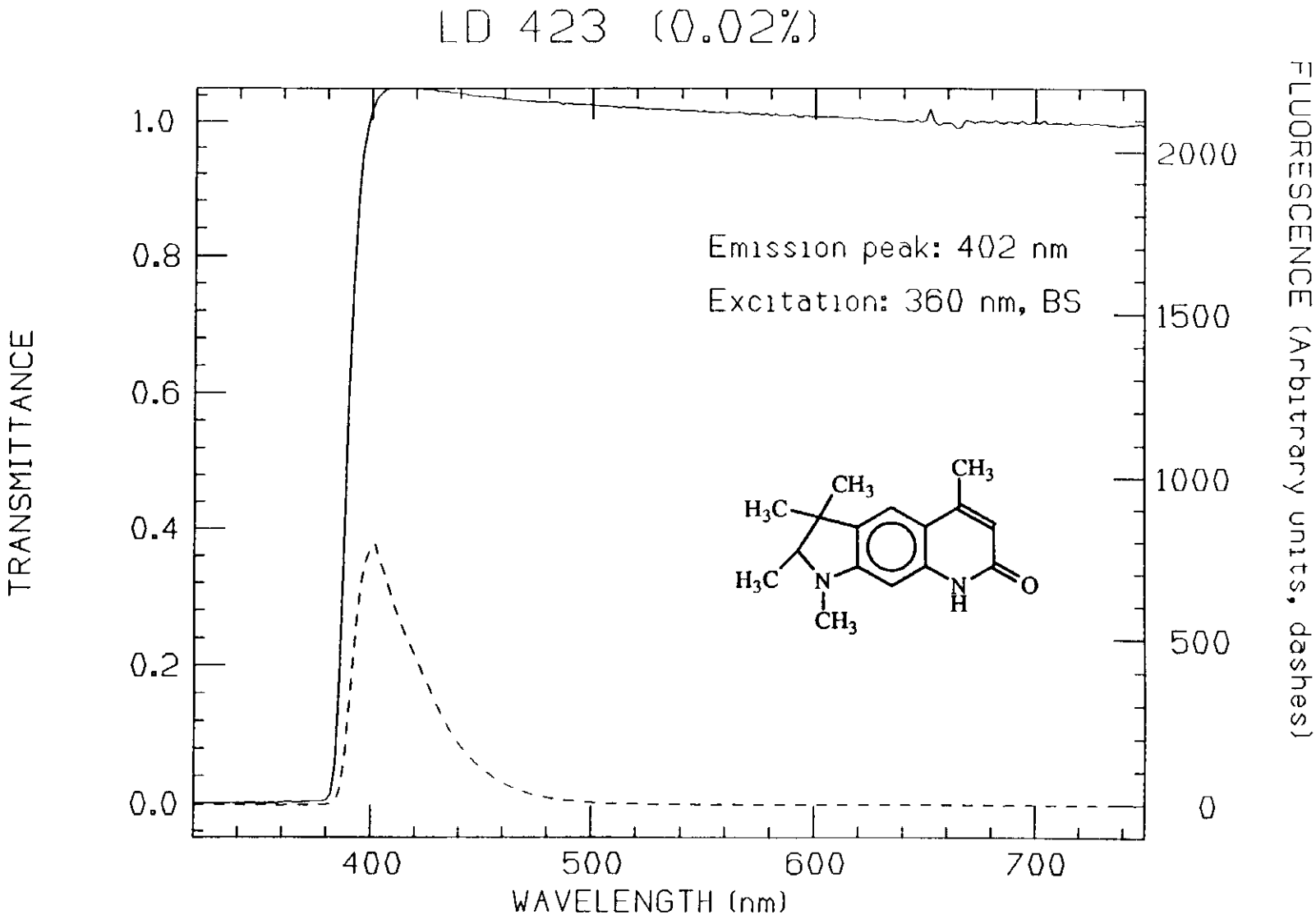

FN548/DICLFN (0.02%)
TRANSMITTANCE
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
WAVELENGTH (nm)
FLUORESCENCE (Arbitrary units, dashes)
2000
1500
1000
500
0
Emission peak: No light
Excitation: 360 nm, FS
HO
OH
Cl
Cl
O
O
O

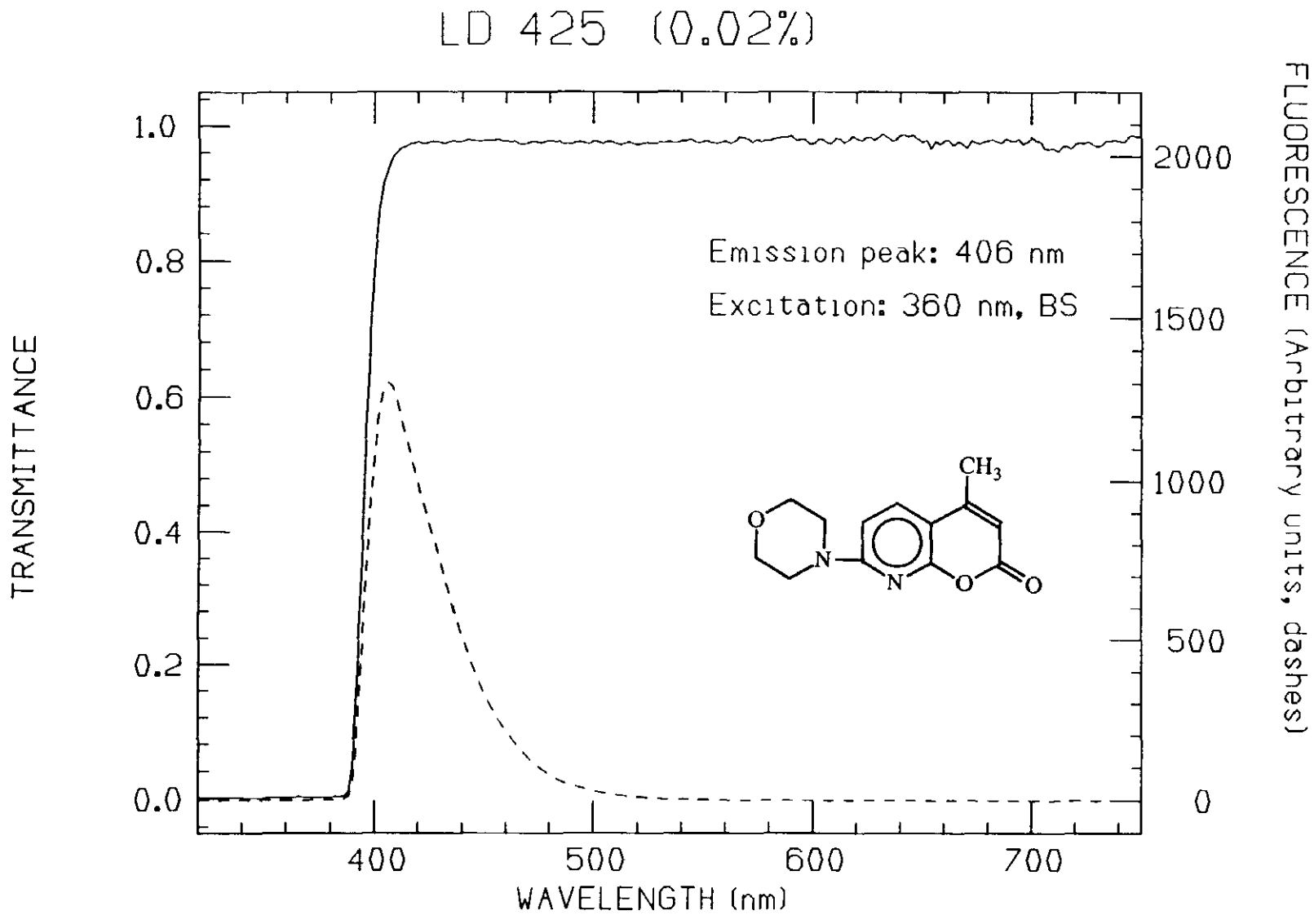

HIDCI + C-E (0.01%)
TRANSMITTANCE
1.0
0.8
0.6
0.4
0.2
0.0
FLUORESCENCE (Arbitrary units, dashes)
2000
1500
1000
500
0
Emission peak: No Light
Excitation: 400 nm, BS
400
500
600
700
WAVELENGTH (nm)

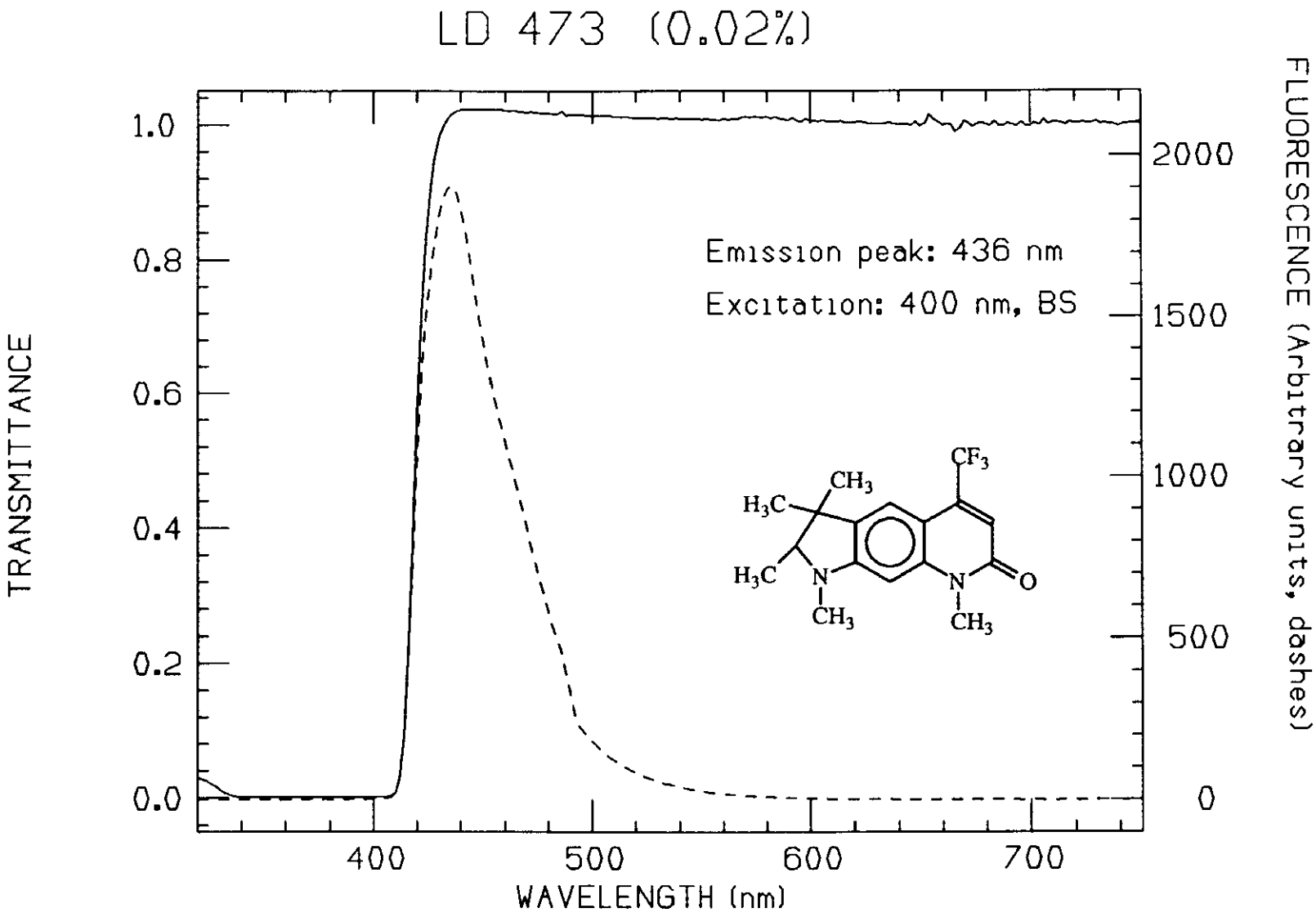

ISCNFN (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: No light
Excitation: 313 nm, FS
HO
O
OH
O
O
S=C=N

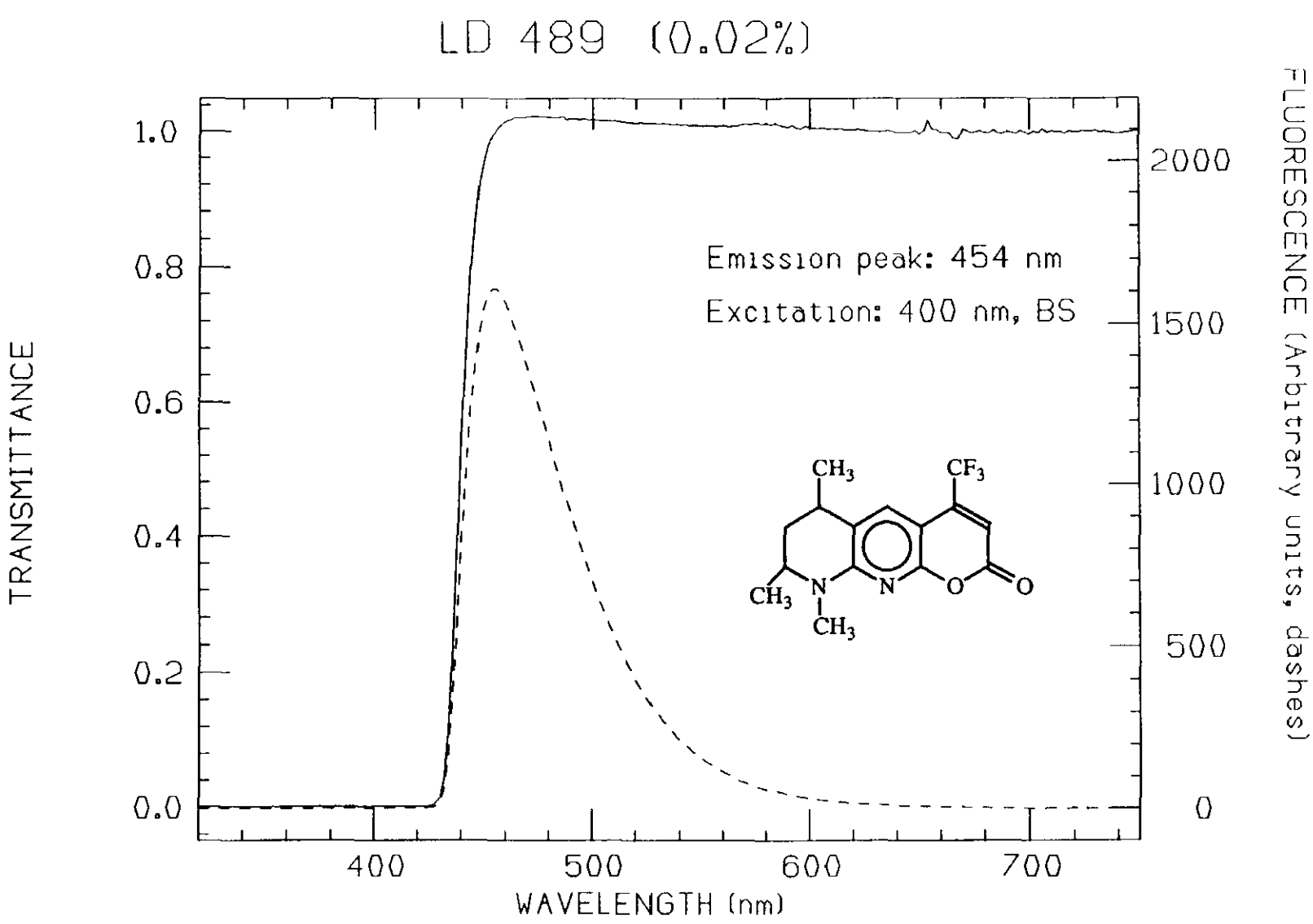
KITON RED 620 (0.02%)

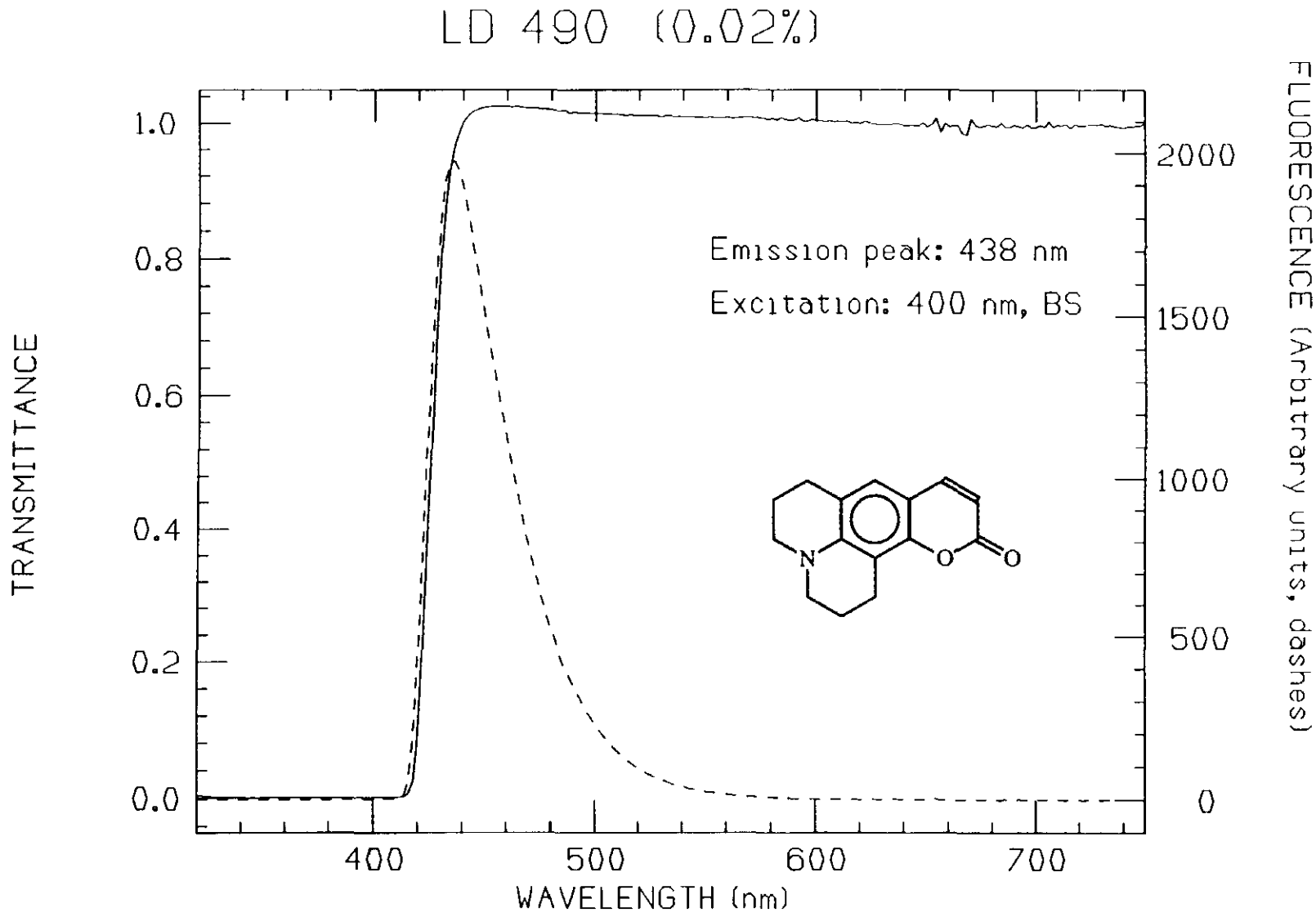


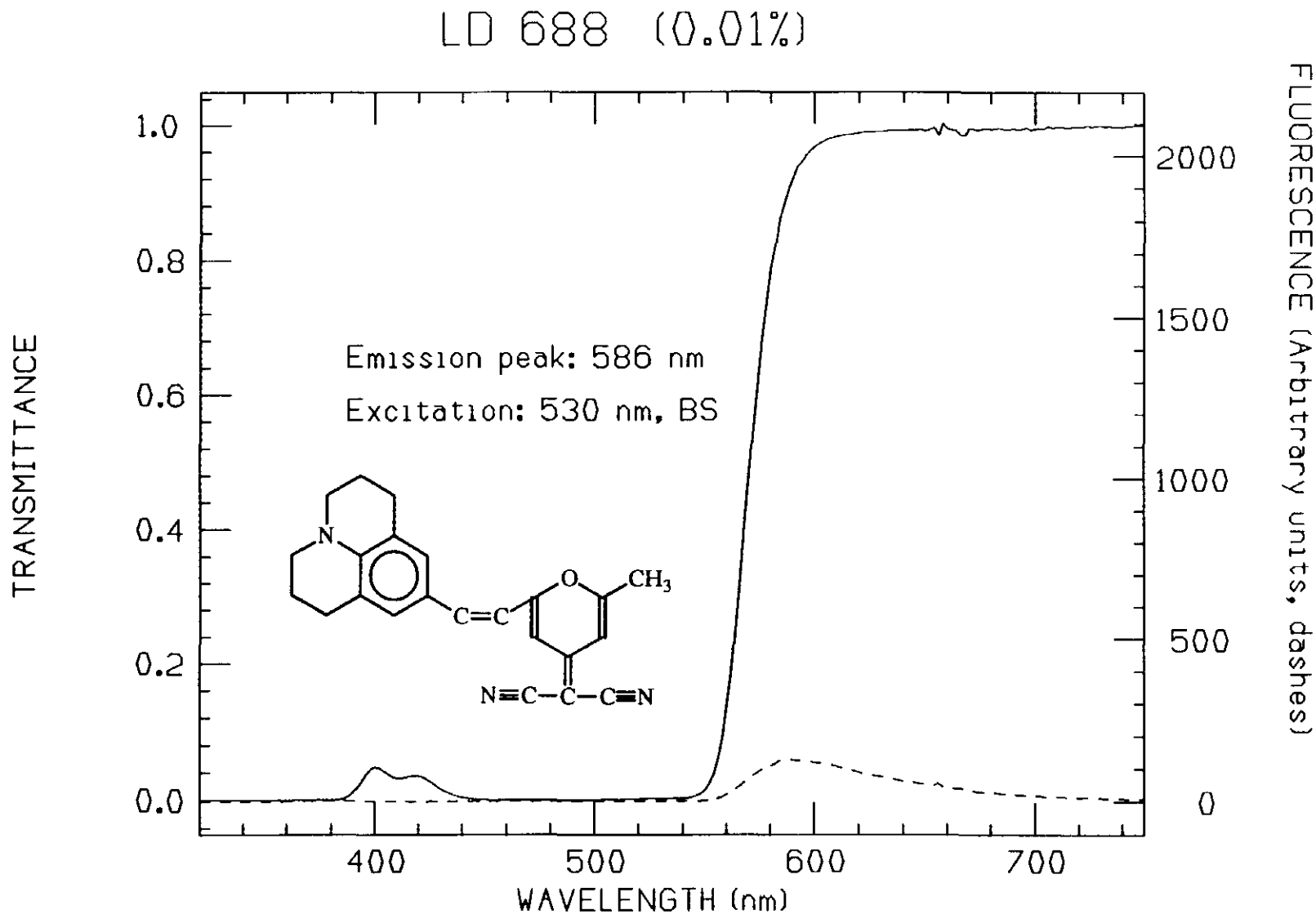

LD 423 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
Emission peak: 402 nm
Excitation: 360 nm, BS
CH3
H3C
CH3
H3C
N
CH3
N
H
O

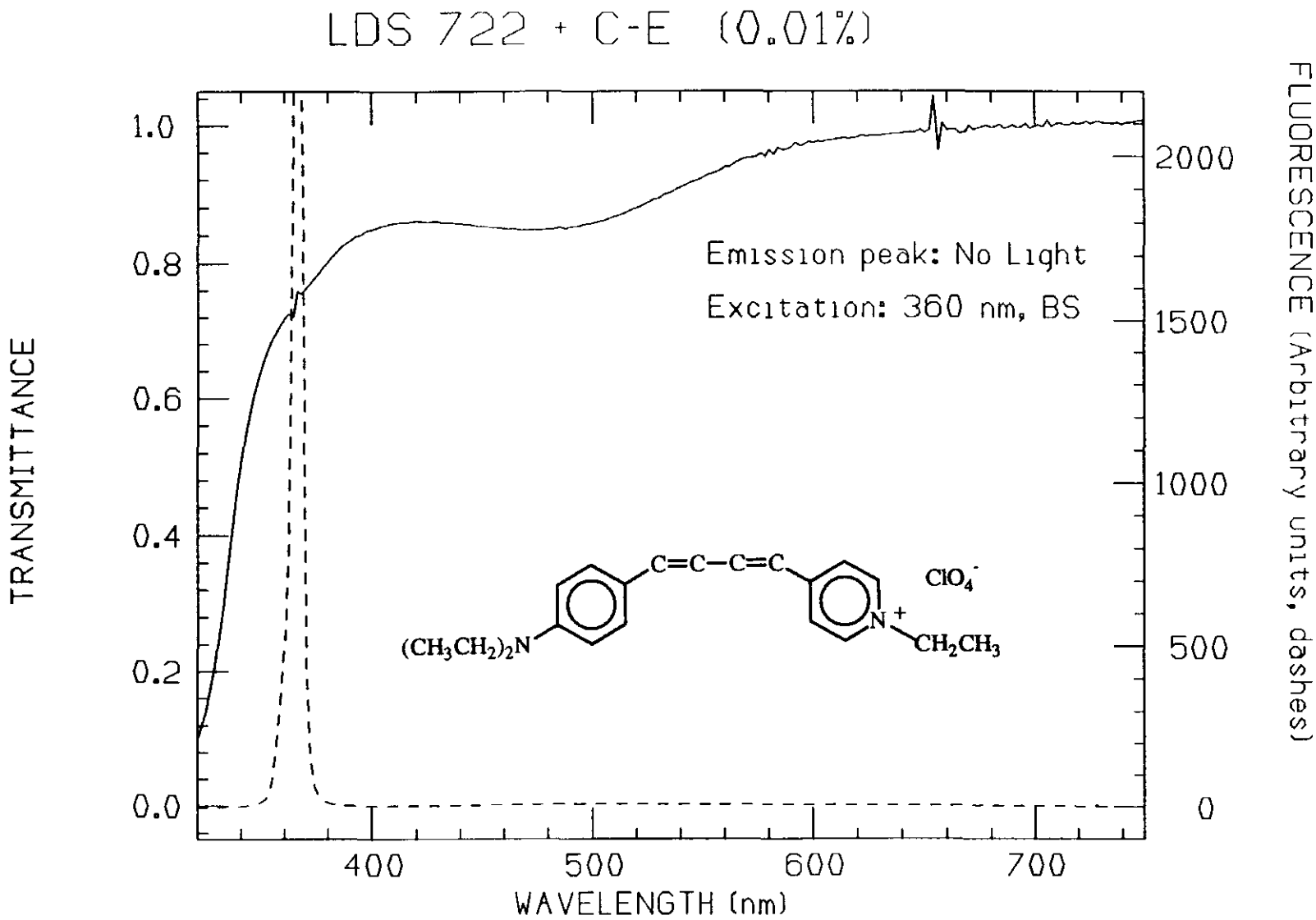

LD 425 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 406 nm
Excitation: 360 nm, BS
CH3
O
N
N
O
O

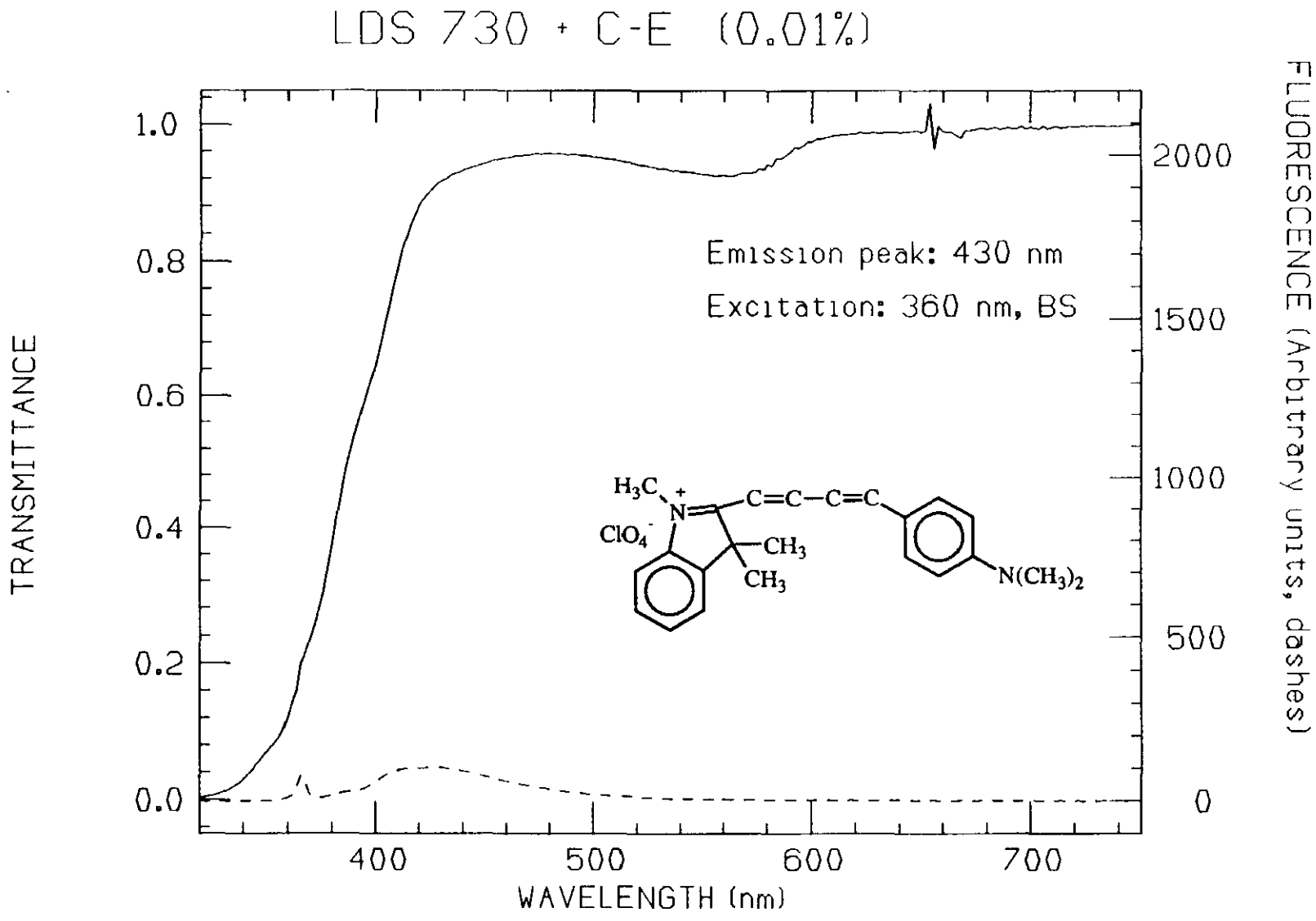

LD 473 (0.02%)
TRANSMITTANCE
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
WAVELENGTH (nm)
2000
1500
1000
500
0
FLUORESCENCE (Arbitrary units, dashes)
Emission peak: 436 nm
Excitation: 400 nm, BS
CF3
CH3
H3C
H3C
N
CH3
N
CH3
O

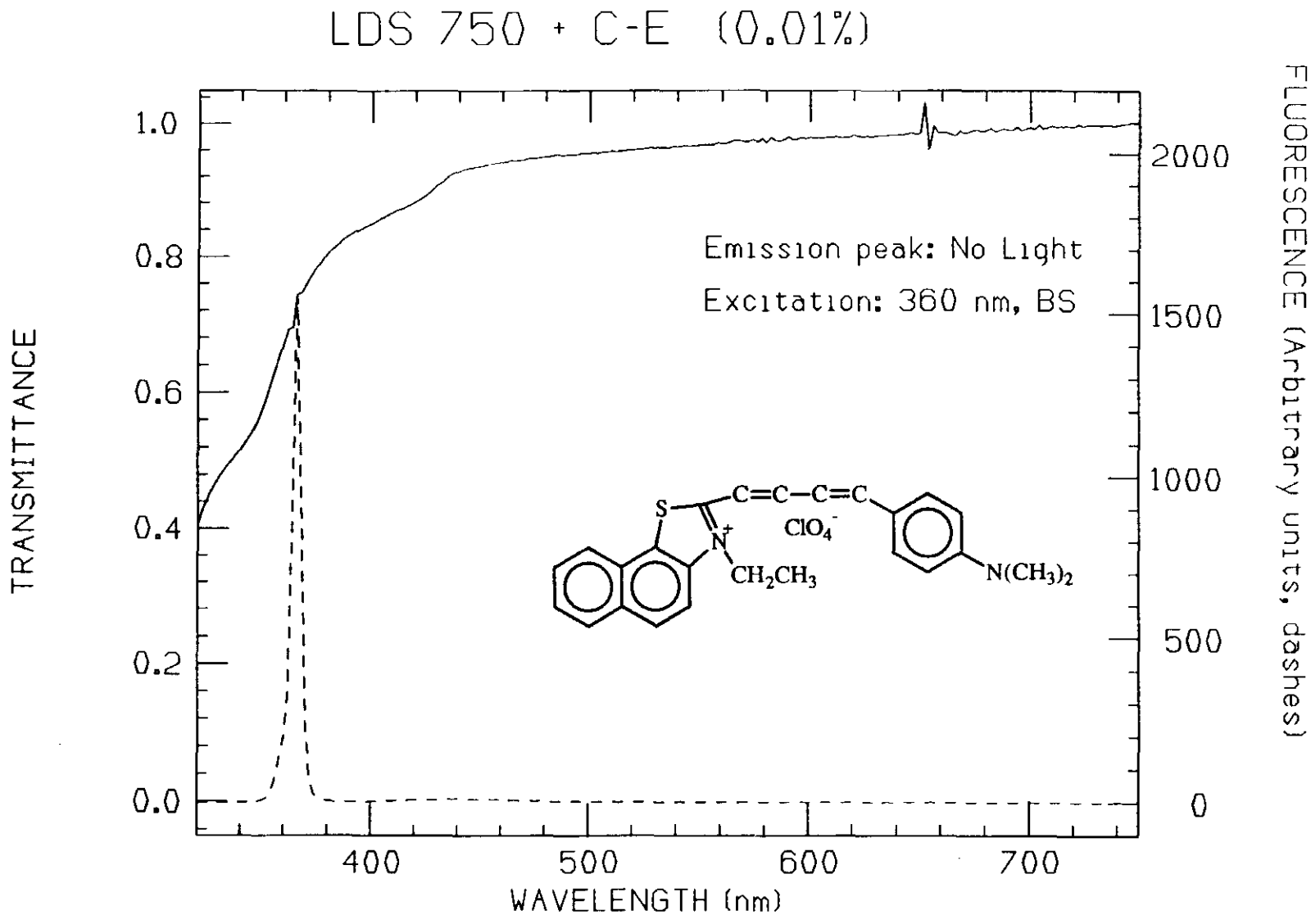

LD 489 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
Emission peak: 454 nm
Excitation: 400 nm, BS
CH3
CF3
CH3
N
N
O
O
CH3

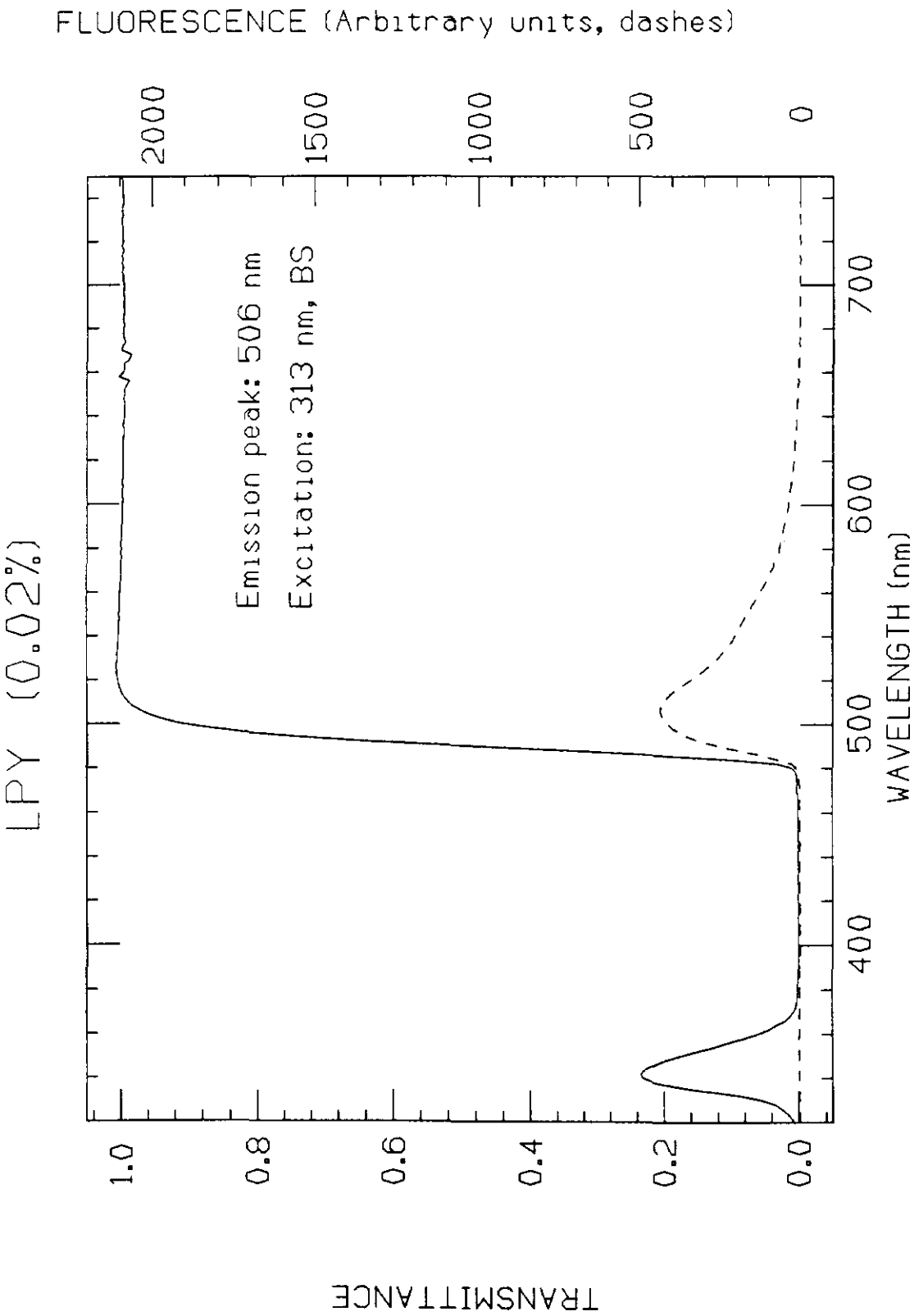

LD 490 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 438 nm
Excitation: 400 nm, BS
N
O
O

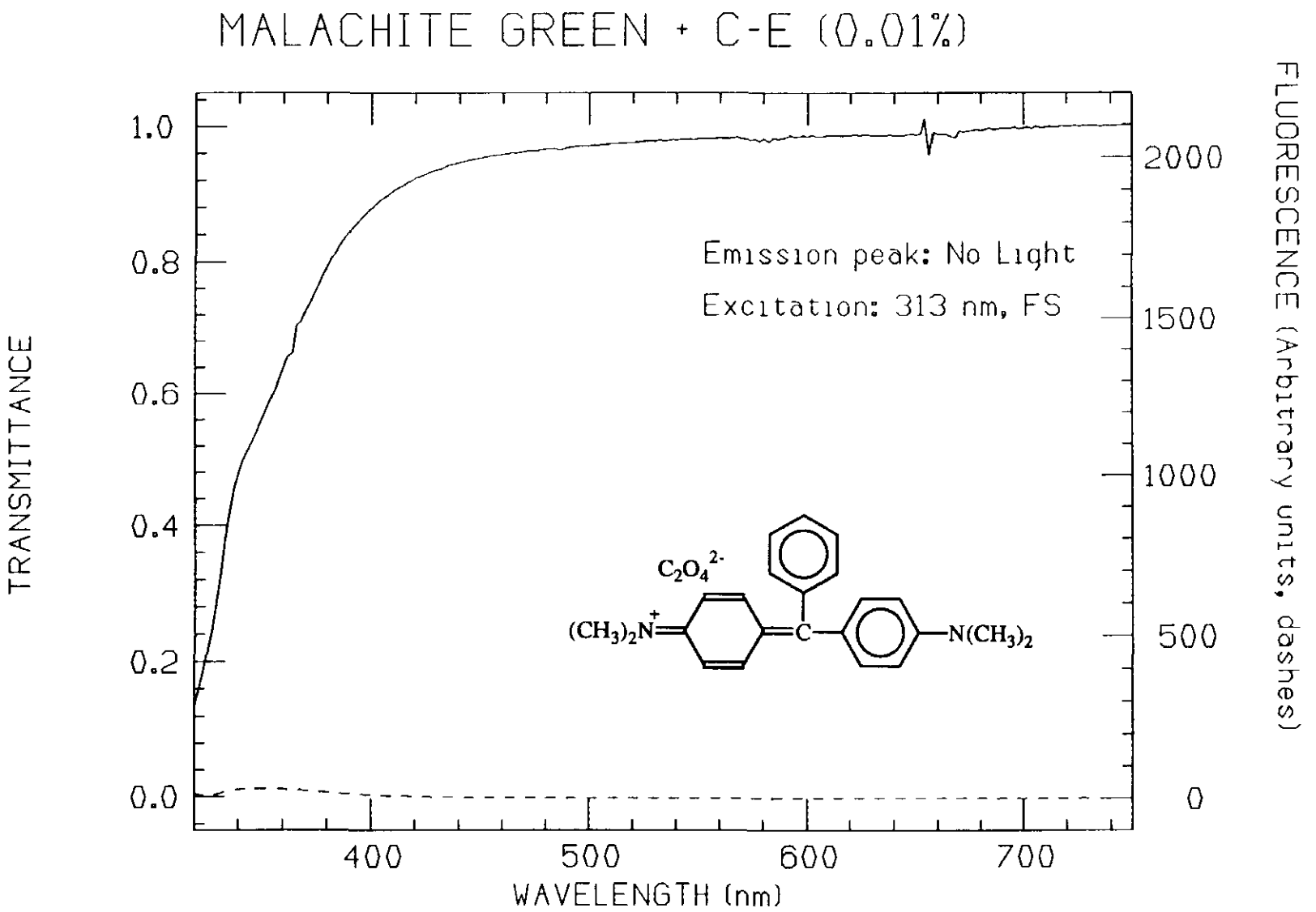

LD 688 (0.01%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 586 nm
Excitation: 530 nm, BS
N
O
CH3
C=C
N≡C–C–C≡N

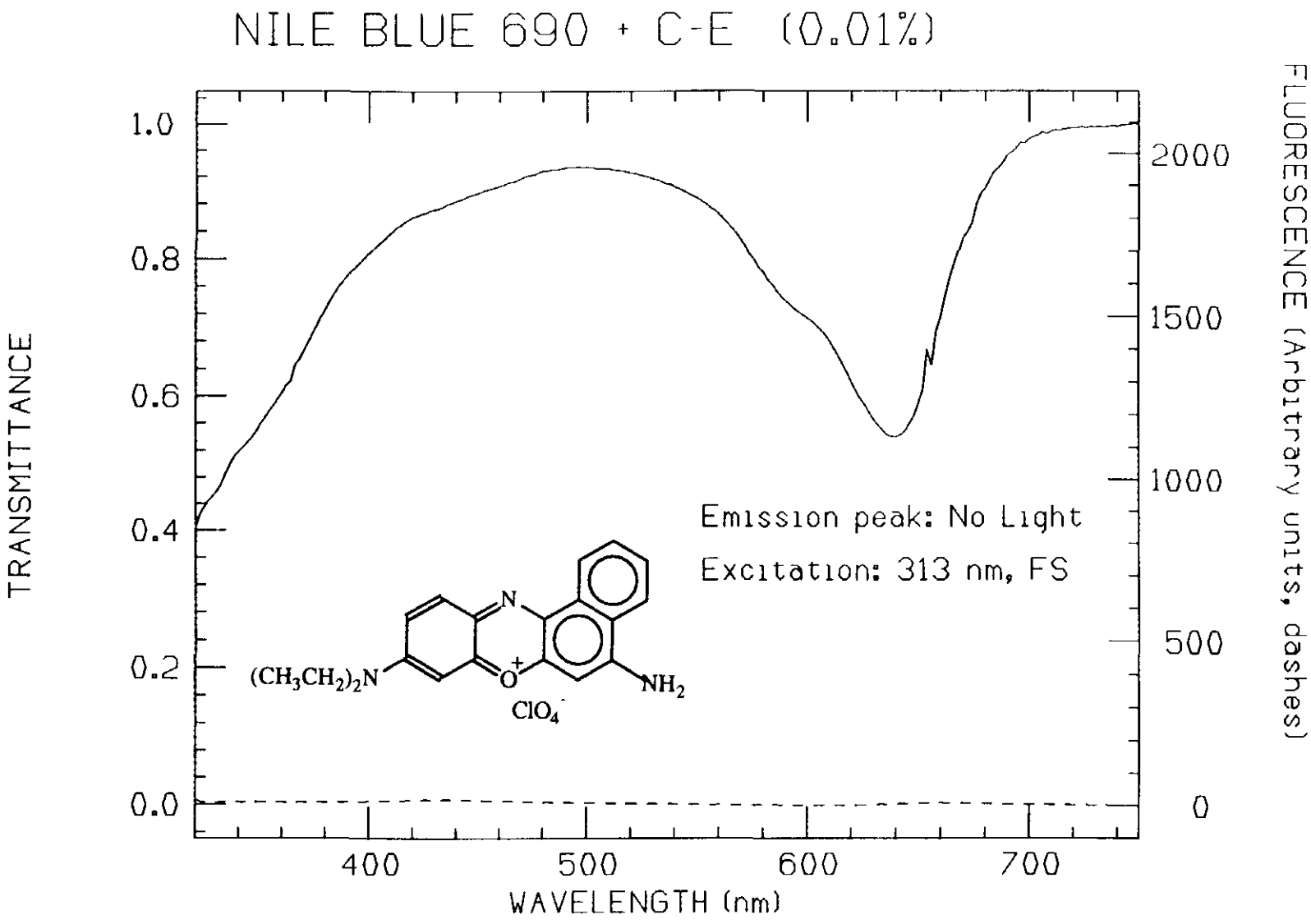

LDS 722 + C-E (0.01%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: No Light
Excitation: 360 nm, BS
C=C-C=C
ClO4-
(CH3CH2)2N
N+
CH2CH3

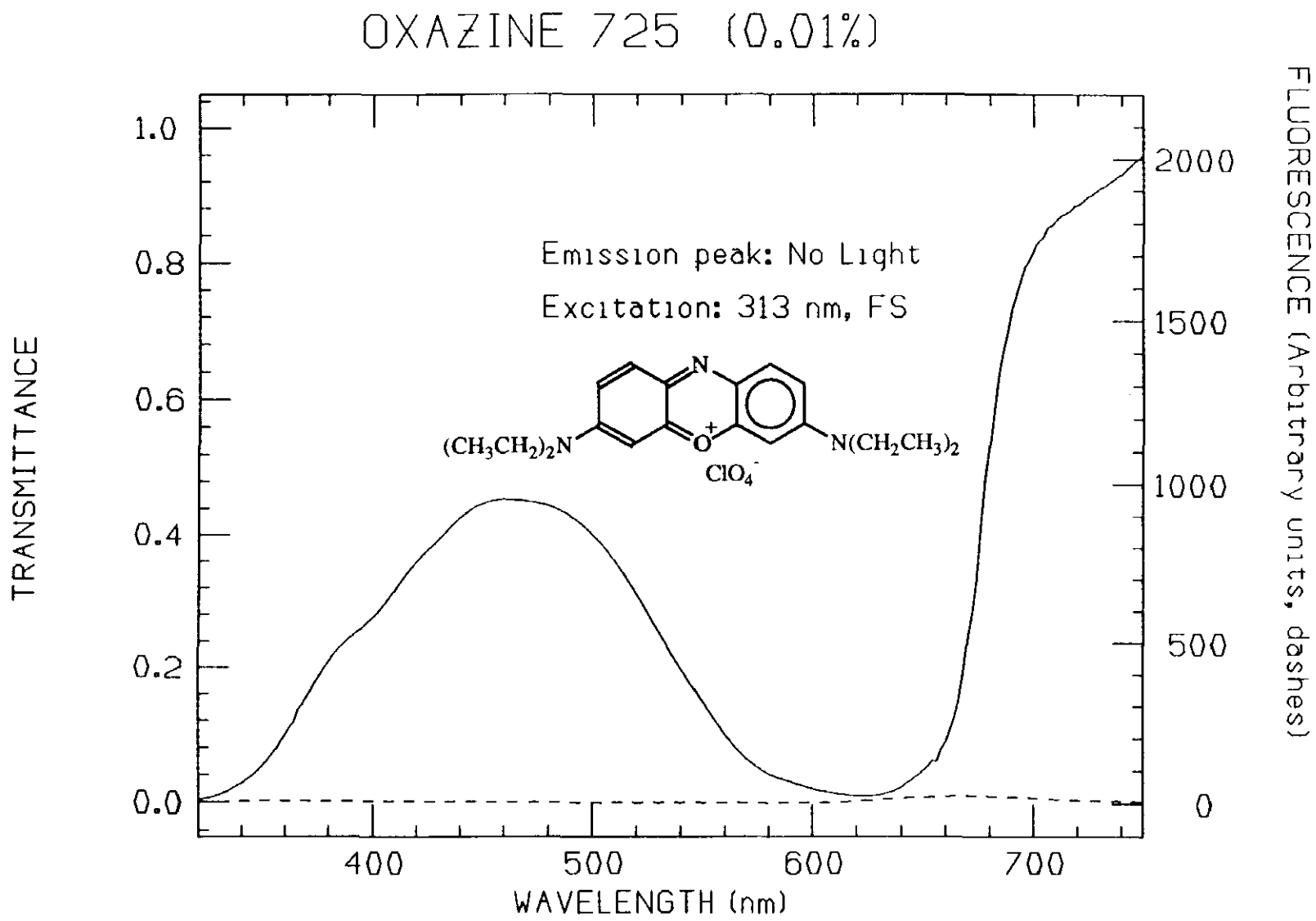

LDS 730 + C-E (0.01%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: 430 nm
Excitation: 360 nm, BS
H3C
N+
ClO4-
C=C-C=C
CH3
CH3
N(CH3)2

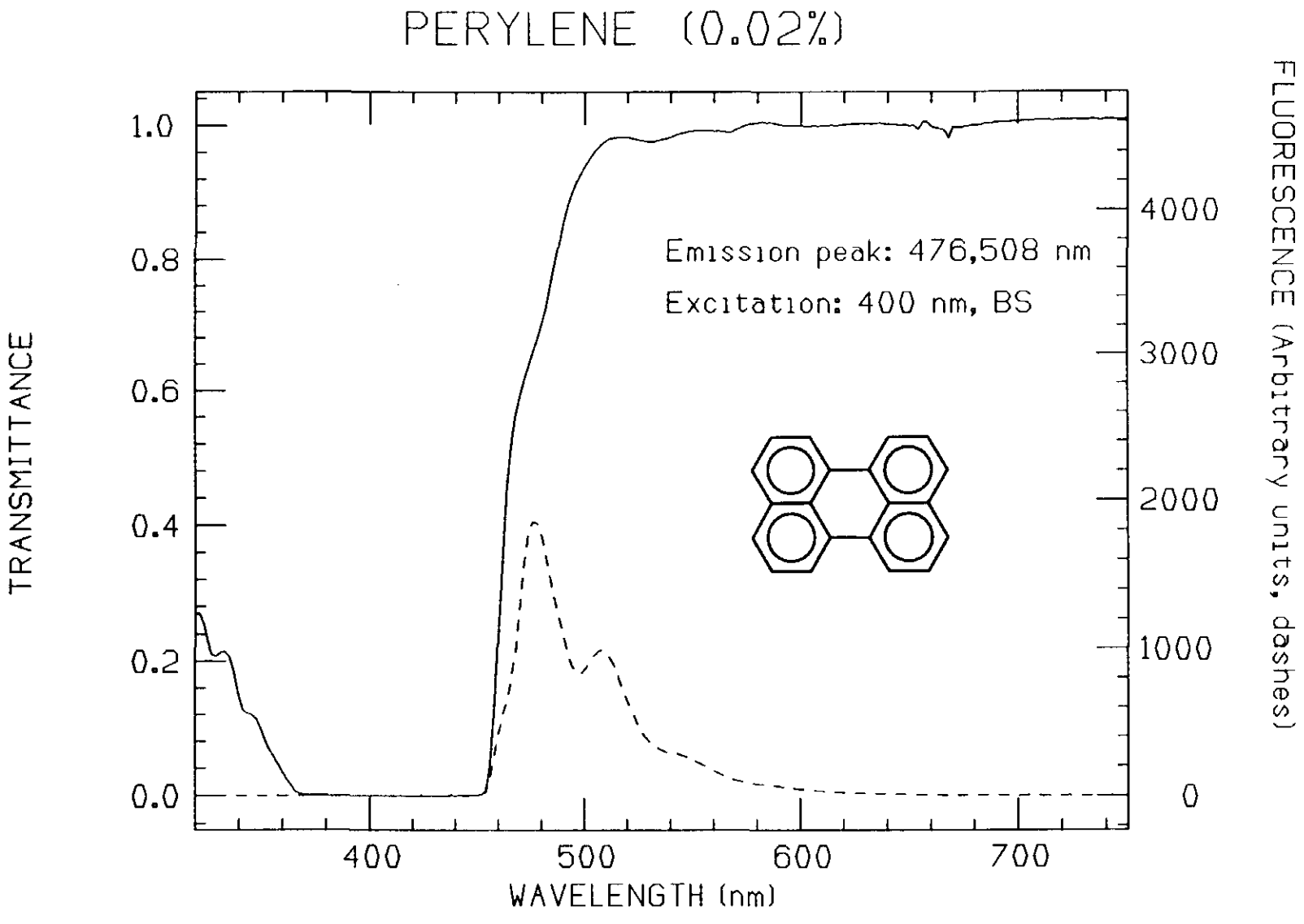

LDS 750 + C-E (0.01%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: No Light
Excitation: 360 nm, BS
S
C=C-C=C
ClO4-
N+
CH2CH3
N(CH3)2

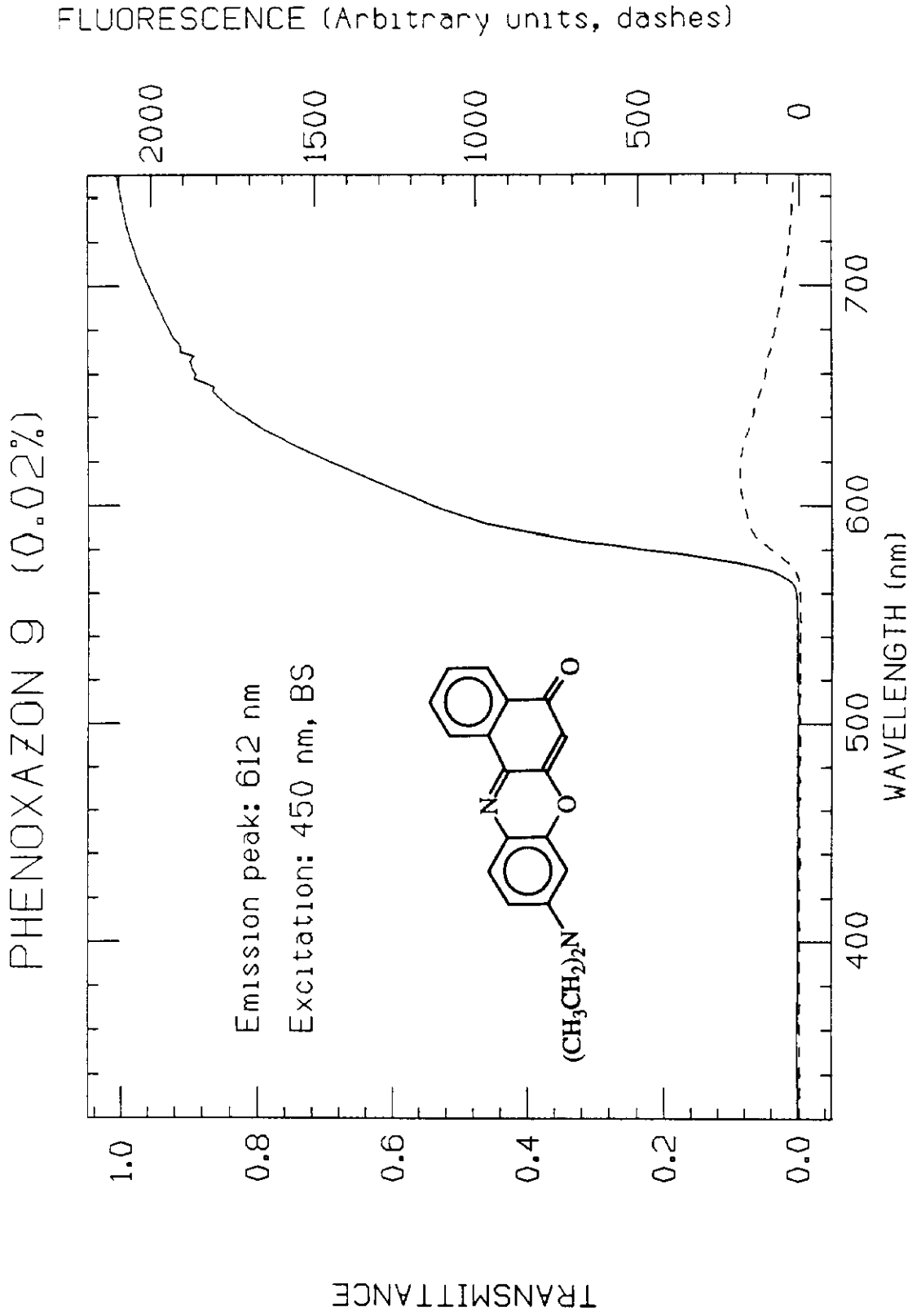

FLUORESCENCE (Arbitrary units, dashes)
2000
1500
1000
500
0
LPY (0.02%)
Emission peak: 506 nm
Excitation: 313 nm, BS
700
600
500
400
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
TRANSMITTANCE

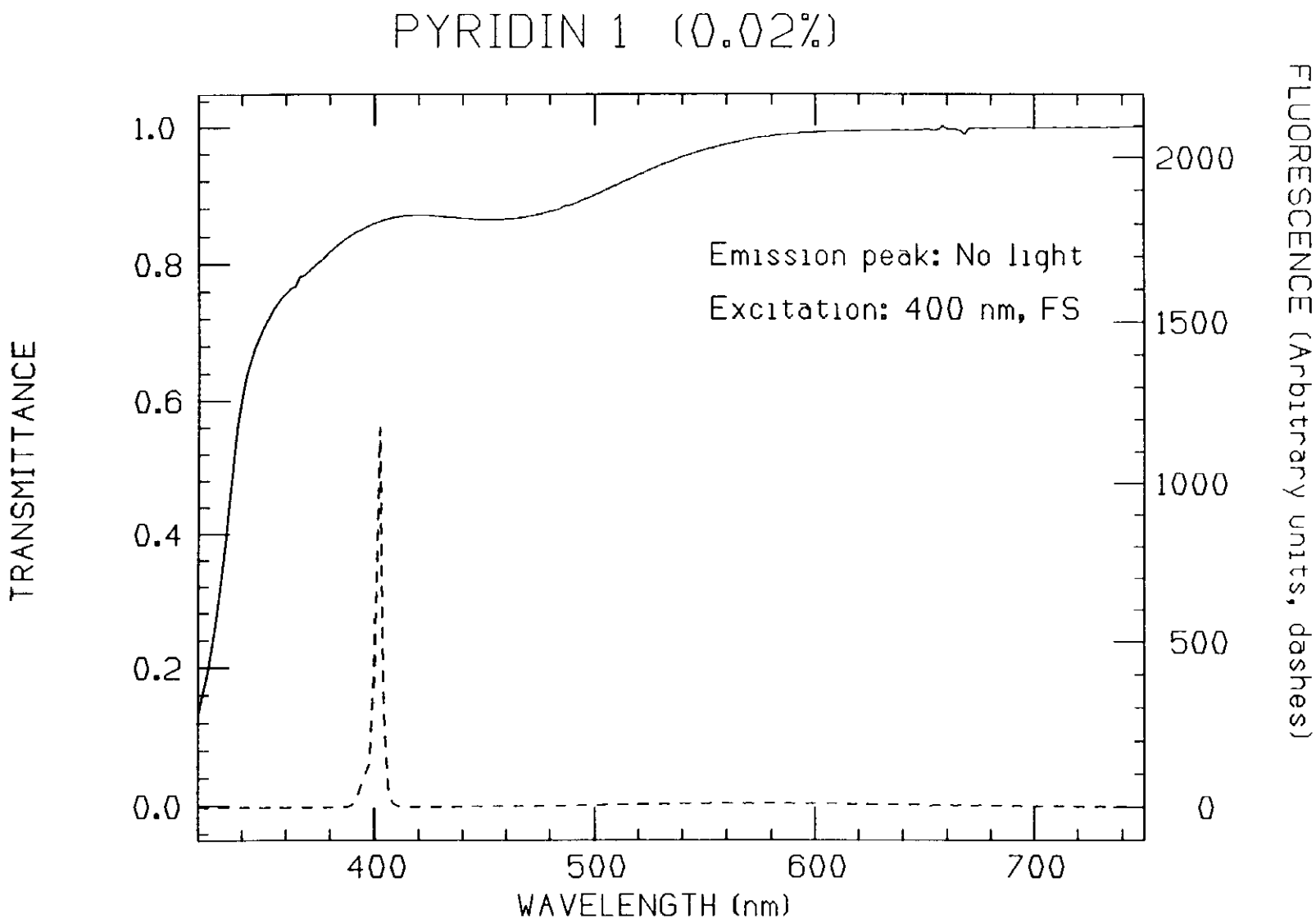

MALACHITE GREEN + C-E (0.01%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: No Light
Excitation: 313 nm, FS
$C_2O_4^{2-}$
$(CH_3)_2N^+$
C
$N(CH_3)_2$

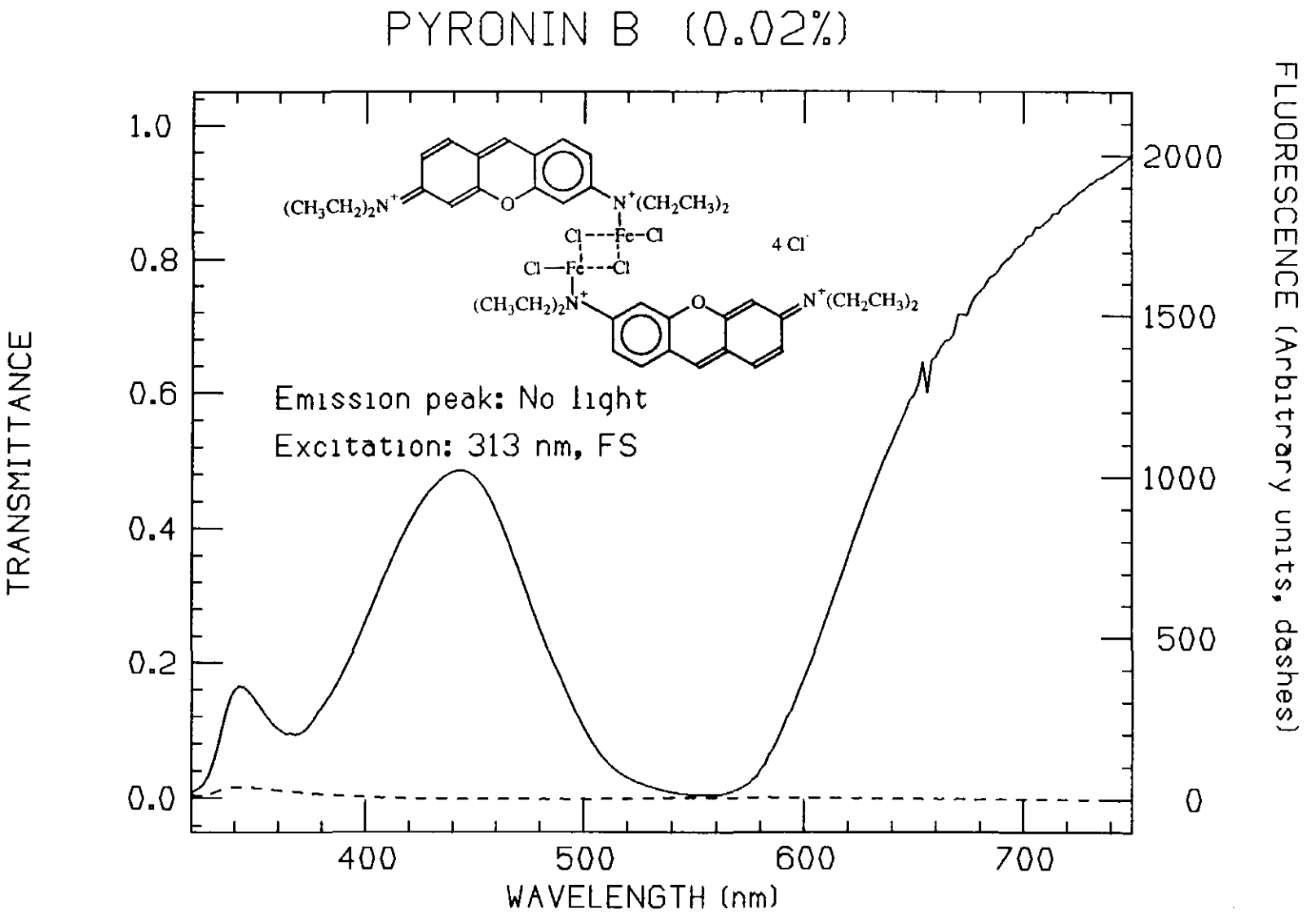

NILE BLUE 690 + C-E (0.01%)
TRANSMITTANCE
1.0
0.8
0.6
0.4
0.2
0.0
FLUORESCENCE (Arbitrary units, dashes)
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: No Light
Excitation: 313 nm, FS
(CH3CH2)2N
NH2
ClO4

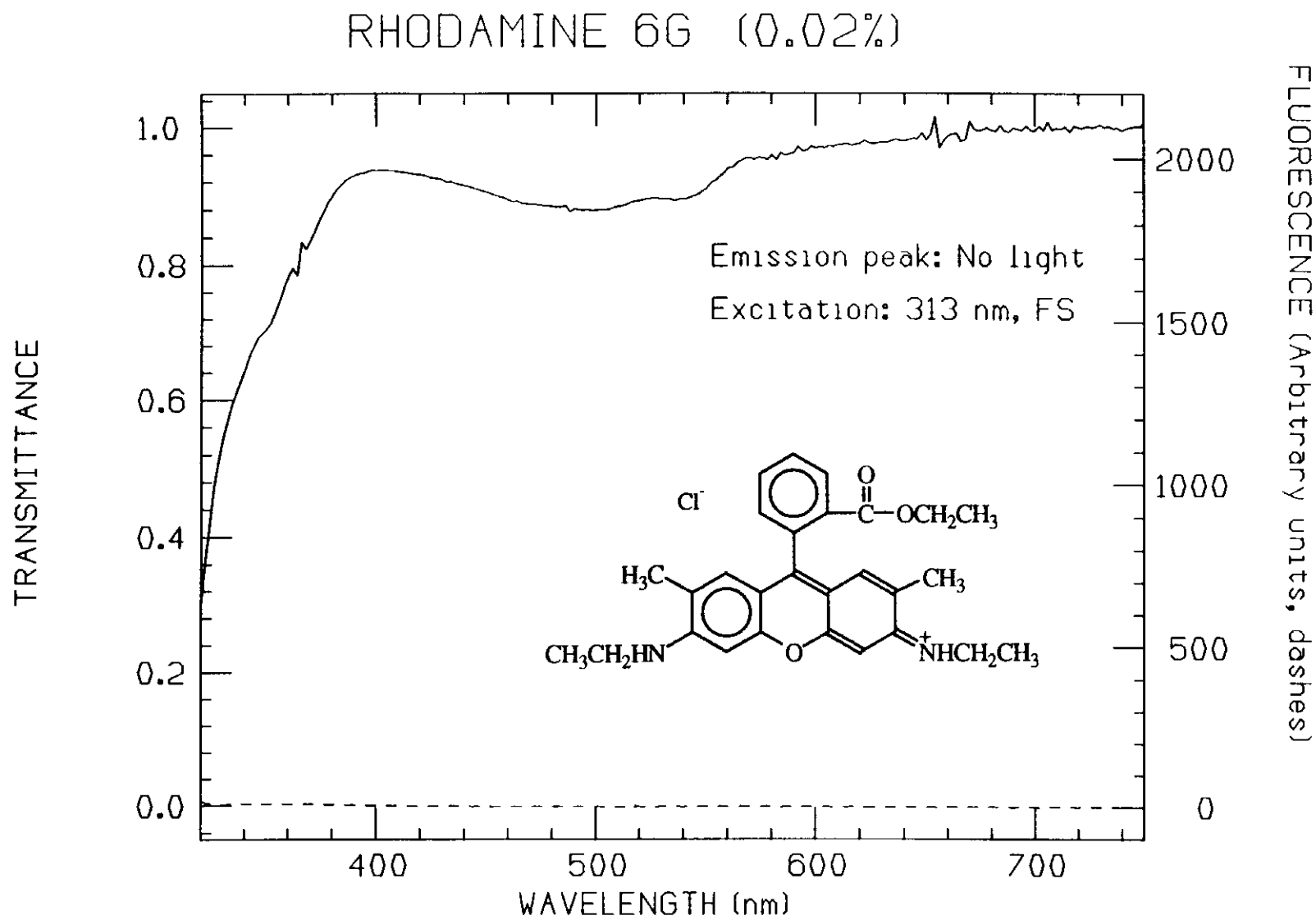

OXAZINE 725 (0.01%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
Emission peak: No Light
Excitation: 313 nm, FS
(CH3CH2)2N
N(CH2CH3)2
ClO4-

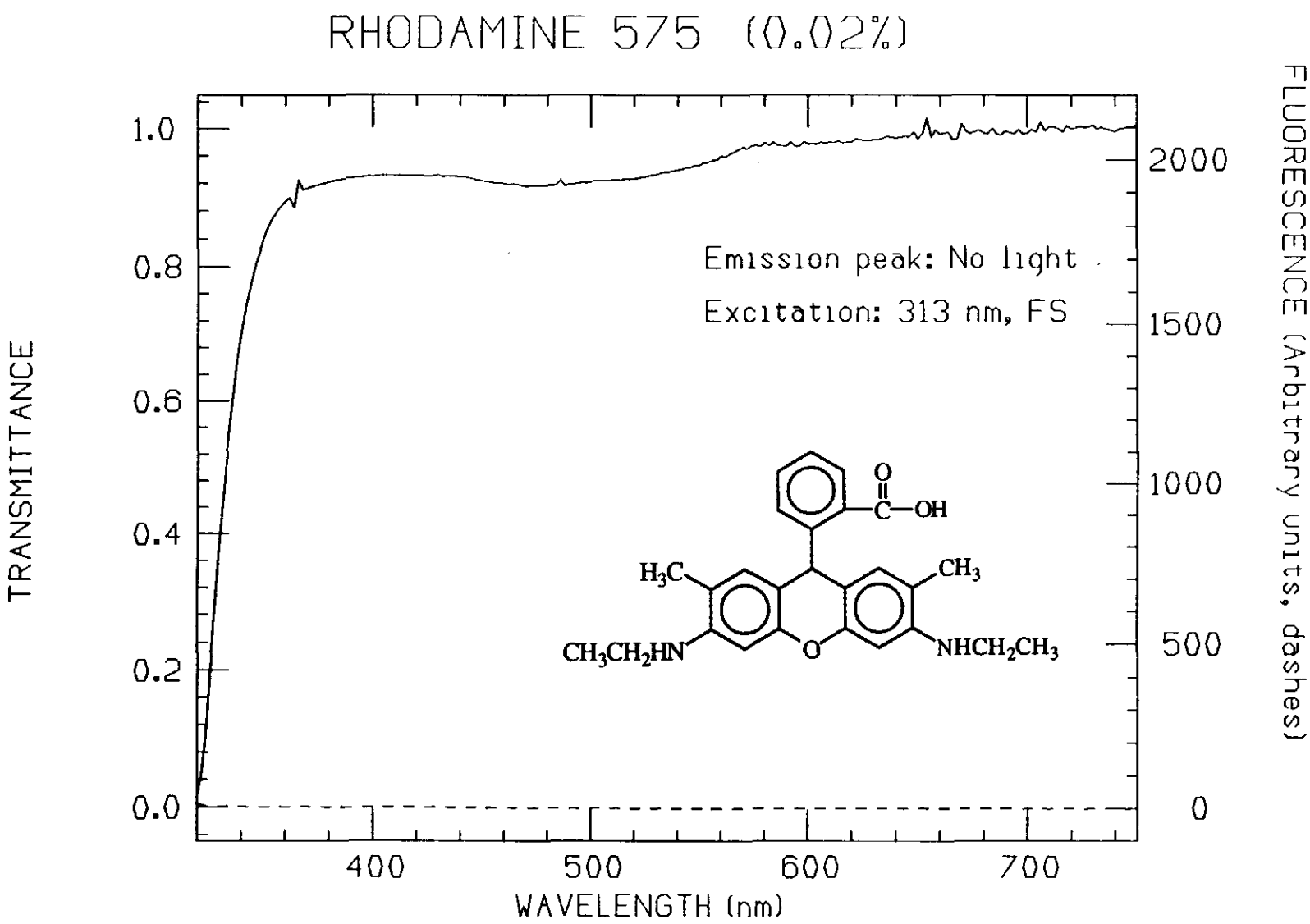

PERYLENE (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
4000
3000
2000
1000
0
Emission peak: 476,508 nm
Excitation: 400 nm, BS

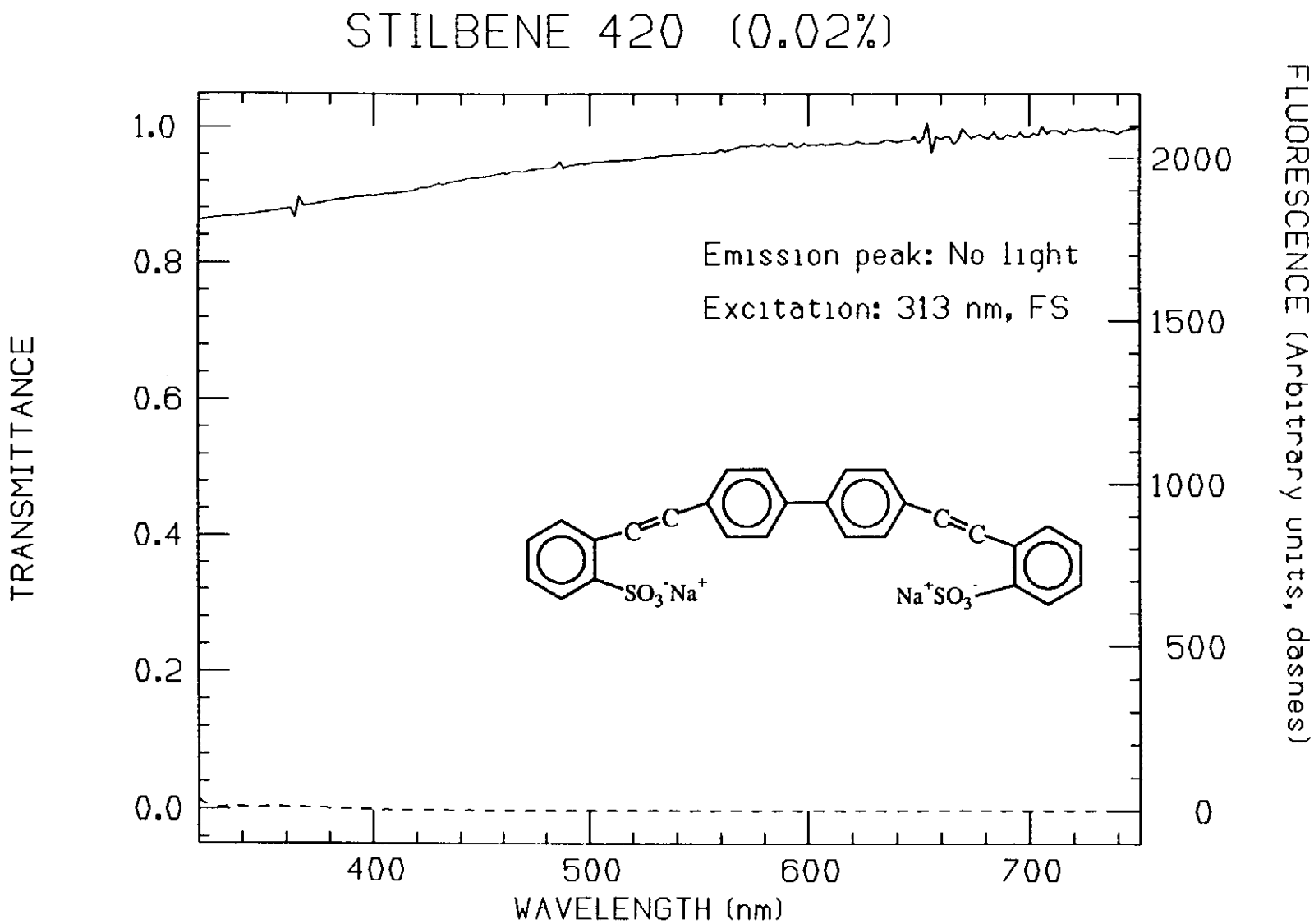

FLUORESCENCE (Arbitrary units, dashes)
2000
1500
1000
500
0
PHENOXAZON 9 (0.02%)
Emission peak: 612 nm
Excitation: 450 nm, BS
O
N
O
(CH3CH2)2N
700
600
500
400
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
TRANSMITTANCE


PYRIDIN 1 (0.02%)
TRANSMITTANCE
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
WAVELENGTH (nm)
Emission peak: No light
Excitation: 400 nm, FS
FLUORESCENCE (Arbitrary units, dashes)
2000
1500
1000
500
0


PYRONIN B (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
Emission peak: No light
Excitation: 313 nm, FS
4 Cl⁻


RHODAMINE 6G (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: No light
Excitation: 313 nm, FS
Cl⁻
O
C—OCH₂CH₃
H₃C
CH₃
CH₃CH₂HN
O
NHCH₂CH₃


RHODAMINE 575 (0.02%)
TRANSMITTANCE
FLUORESCENCE (Arbitrary units, dashes)
1.0
0.8
0.6
0.4
0.2
0.0
2000
1500
1000
500
0
400
500
600
700
WAVELENGTH (nm)
Emission peak: No light
Excitation: 313 nm, FS
O
C—OH
H3C
CH3
CH3CH2HN
O
NHCH2CH3


STILBENE 420 (0.02%)
TRANSMITTANCE
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
WAVELENGTH (nm)
FLUORESCENCE (Arbitrary units, dashes)
2000
1500
1000
500
0
Emission peak: No light
Excitation: 313 nm, FS
SO3-Na+
Na+SO3-

APPENDIX A: LIST OF DOPANT NAMES

DOPANTS	CAS #	NAME
ACRIDINE O B	494-38-2	3,6-bis(dimethylamino)acridine
ACRIDINE Y	135-49-9	3,6-diamino-2,7-dimethylacridine hydrochloride
ACRIFLAVINE	8048-52-0	acriflavinium chloride
BBOT	7128-64-5	2,5-bis-5'-tertbutyl-benzoxazolyl-(2')-thiophene
bis-MSB	13280-61-0	1,4-bis(2-methylstyryl)benzene
BSFL	*	brilliantsulfaflavin
C4	90-33-5	7-hydroxy-4-methyl-2-oxo-2H-1-benzopyran
C35/C481	41934-47-8	7-(diethylamino)-4-(trifluoromethyl)-2H-1-benzopyran-2-one
C138	62669-74-3	7-(dimethlyamino)-2-3-dihydrocyclopenta[c][i]benzopyran-4(1H)-one
C153K/C153LP	53518-18-6	2,3,6,7-tetrahydro-9-(trifluoromethyl-1H,5H,11H-[1]benzopyrano[6,7,8-ij]quinolizine-11-one
C311	87-01-4	7-dimethylamino-4-methylcoumarin
C314T	113869-06-0	2,3,6,7-tetrahydro-1,1,7,7-tetramethyl-11-oxo-1H,5H,11H(1)benzopyrano(6,7,8-ij)quinolizine-10-carboxylic acid ethyl ester
C338	62669-75-4	1,1-dimethylethyl-2,3,6,7-tetrahydro-11-oxo-1H,5H,11H(1)benzopyrano(6,7,8-ij)quinolizine-10-carboxylate
C339	62669-73-2	6,7,8,9-tetrahydro-4-methyl-2H-pyrano-[3,2-g]quinolin-2-one
C440	26093-31-2	7-amino-4-methyl-2H-1-benzopyran-2-one
C445	28821-18-3	7-(ethylamino)-4-methyl-2H-1-benzopyran-2-one
C450	26078-25-1	7-(ethylamino)-4,6-dimethyl-2H-1-benzopyran-2-one
C460	91-44-1	7-(diethylamino)-4-methyl-2H-1-benzopyran-2-one
C466/LD466	20571-42	7-(diethylamino)-2H-1-benzopyran-2-one
C478	41175-45-5	2,3,6,7,10,11-hexahydro-1H,5H-cyclopenta[3,4][1]benzopyran[6,7,8-ij]quinolizin-12(9H)-one
C480	41267-76-9	2,3,6,7-tetrahydro-9-methyl-1H,5H,11H-[1]benzopyrano[6,7,8-ij]quinolizine-11-one
C485	53518-14-2	7-(dimethylamino)-4-(trifluoromethyl)-2H-1-benzopyran-2-one
C487	*	*
C490	53518-15-3	7-amino-4-(trifouoromethyl)-2H-1-benzopyran-2-one
C498	87331-48-4	2,3,6,7-tetrahydro-10-(methylsulfonyl)-1H,5H,11H-[1]benzopyrano[6,7,8-ij]quinolizin -11-one
C500	52840-38-7	7-(ethylamino)-4-(trifluoromethyl)-2H-1-benzopyran-2-one
C503	55804-70-1	7-(ethylamino)-6-methyl-4-(trifluoromethyl)-2H-1-benzopyran-2-one
C504	55804-66-5	ethyl-2,3,6,7-tetrahydro-11-oxo-1H,5H,11H(1)benzopyrano(6,7,8-ij)quinolizine-10-carboxylate
C510	87349-92-6	2,3,6,7-tetrahydro-10-(3-pyridinyl)-1H,5H,11H-[1]benzopyrano[6,7,8-ij]quinolizin-11-one
C515	41044-12-6	7-(dimethylamino)-3-(1-methyl-1H-benzimidazol-2-yl)-2H-1-benzopyran-2-one

DOPANTS	CAS #	NAME
C519	55804-65-4	2,3,6,7-tetrahydro-11-oxo-1H,5H,11H-[1]benzopyrano[6,7,8-ij]quinolizine-10-carboxylic acid
C521	55804-67-6	10-acetyl-2,3,6,7-tetrahydro-1H,5H,11H-[1]benzopyrano[6,7,8-ij]quinolizin-11-one
C522	53518-19-7	6,7,8,9-tetrahydro-9-methyl-4-(trifluoromethyl)-2H-pyrano[3,2-g]quinolin-2-one
C523	55804-68-7	2,3,6,7-tetrahydro-11-oxo-1H,5H,11H-[1]benzopyrano[6,7,8-ij]quinolizine-10-carbonitrile
C525	87331-47-3	10-(2-benzoxazolyl)-2,3,6,7-tetrahydro-1H,5H,11H-[1]benzopyrano[6,7,8-ij]quinolizin-11-one
C535	27425-55-4	3-(1H-benzimidazole-2-yl)-7-(diethylamino)-2H-[1]benzopyran-2-one
C540	38215-36-0	3-(2-benzothiazolyl)-7-(diethylamino)-2H-[1]benzopyran-2-one
C545	85642-11-1	10-(2-benzothiazolyl)-2,3,6,7-tetrahydro-1H,5H,11H-[1]benzopyrano[6,7,8-ij]quinolizin-11-one
CBSTY 3	*	7-dimethylamino-4-methylquinolone-2
CBSTY 124	19840-99-4	7-amino-4-methyl-2(1H)-quinolinone
DASBTI	*	*
DASPI	*	*
DCI-2	*	*
DCM/DCM2	51325-91-8	[2-[2-[4-(dimethylamino)phenyl]ethenyl]-6-methyl-4H-pyran-4-ylidene]-propanedinitrile
DiACFN	596-09-8	fluorescein diacetate
DiBRFN	596-03-2	4',5'-dibromofluorescein
DMETCI	*	dimethyl-9-ethylthiacarbocyanine Iodide
DMPOPOP	3073-87-8	1,4-bis(4-methyl-5-phenyloxazol-2-yl)-benzene
DOCI	*	diethyloxacarbocyanine Iodide
DODCI	14806-50-9	3-ethyl-2-[5-(3-ethyl-2(3H)-benzoxazolyidene)-1,3-pentadienyl]-benzoxazolium iodide
DQOCI	*	*
DTCI	*	diethylthiacarbocyanine Iodide
DTDCI	514-73-88	3-ethyl-2-[5-(3-ethyl-2(3H)-benzthiazolyidene)-1,3-pentadienyl]-benzthiazolium iodide
F555	19125-99-6	2-butyl-6-(butylamino)-1H-benz[de]isoquinoline-1,3(2H)-dione
FN548/DiCLFN	76-54-0	2',7'-dichloro-3',6'-dihydroxy-spiro[isobenzofuran-1(3H),9'-[9H]xanthen-3-one
HIDC IODIDE	36536-22-8	2-[5-(1,3-dihydro-1,3,3-trimethyl-2H-indol-2-ylidene)-1,3-pentadienyl]-1,3,3-trimethyl-3H-indolium iodide
ISCNFN	3326-32-7	fluorescein Isothiocyanate Isomer I
KITON RED 620	2609-88-3	N-[6-(diethylamino)-9-(2,4-disulfophenyl)-3H-xanthen-3-ylidene]-N-ethyl-ethanaminium hydroxide
LD423	58336-37-1	1,2,3,8-tetrahydro-1,2,3,3,5-pentamethyl-7H-pyrrolo[3,2-g]quinolin-7-one
LD425	57980-07-1	4-methyl-7-(4-morpholinyl)-2H-pyrano[2,3-b]pyridin-2-one

DOPANTS	CAS #	NAME
LD473	58721-74-7	1,2,3,8-tetrahydro-1,2,3,3,8-pentamethyl-5-(trifluoromethyl)-7H-pyrrolo[3,2-g]quinolin-7-one
LD489	62377-37-1	6,7,8,9-tetrahydro-6,8,9-trimethyl-4-(trifluoromethyl)-2H-pyrano[2,3-b][1,8]naphthyridin-2-one
LD490	58336-35-9	2,3,6,7-tetrahydro-1H,5H,11H,[1]benzopyrano[6,7,8-ij]-quinoliz-11-one
LD688	51325-95-2	2-methyl-6-[2-(2,3,6,7-tetrahydro-1H,5H-benzo[ij]quinolizin-9-yl)ethenyl]-4H-pyran-4-ylidene]-propanedinitrile
LDS722	89846-21-9	4-[4-[4-(dimethylamino)phenyl]-1,3-butadienyl]-1-ethyl-pyridinium perchlorate
LDS730	76433-27-7	2-[4-[4-(dimethylamino)phenyl]-1,3-butadienyl]-1,3,3-trimethyl-3H-indolium perchlorate
LDS750	89872-07-1	2-[4-[4-(dimethylamino)phenyl]-1,3-butadienyl]-3-ethylnaphtho[2,1-d]thiazoliumperchlorate
LPY	*	*
MALACHITE GREEN	18015-76-4	N-[4-[[4-(dimethylamino)phenyl]phenylmethylene]-2,5-cyclohexadien-1ylidene-N-methylmethanaminium ethanedioate(2:2:1)
NILE BLUE	53340-16-2	5-amino-9-(diethylamino)-benzo[a]phenoxazin-7-ium perchlorate
OXAZINE 725	24796-94-9	3,7-bis(diethylamino)-phenoxazin-5-ium perchlorate
PERYLENE	198-55-0	dibenz(de,kl)anthracene
PHENOXAZON 9	7385-67-3	nile red
PYRIDIN1	*	*
PYRONIN B	2150-48-3	(6-(diethylamino)-3H-xanthen-3-ylidine)diethylammonium chloride
RHODAMINE 6G	989-38-8	9-(2-(ethoxycarbonyl)phenyl)-3,6-bis(ethylamino)-2,7-dimethylxanthylium chloride
RHODAMINE575	25152-49-2	2-[6-(ethylamino)-3-(ethylamino)-2,7-dimethyl-3H-xanthen-9-yl]-benzoic acid
STILBENE 420	27344-41-8	2,2'-([1,1'-biphenyl]-4,4'-diyldi-2,1-ethenediyl)bis-benzenesulfonic acid disodium salt

* information not available in MSDS

APPENDIX B: LIST OF FLUORESCENCE MEASUREMENTS

DOPANTS	RADAM#	POLY#	F313	F360	B360	F400	B400	F436	B436	F450	B450
ACRIDINE O B	22	79	X							X	
ACRIDINE Y	22	79	X								
ACRIFLAVINE	22	79	X								
BBOT	22	79	X	X	X						
bis-MSB	22	79	X	X	X						
BSFL	22	78	X			X					
C4	†	76	X								
C35/C481	20	76	X			X	X				
C138	-	76	X	X	X						
C153K/C153LP	20	76	X			X	X				
C311	-	76	X	X	X						
C314T	20	76	X			X	X				
C338	20	76	X			X	X				
C339	-	76	X	X	X						
C440	-	74	X	X	X						
C445	-	74	X	X	X						
C450	-	74	X	X	X						
C460	-	74	X	X	X						
C466/LD466	-	74	X	X	X						
C478	20	74	X	X	X						
C480	20	74	X	X	X						
C485	20	74	X			X	X				
C487	20	74	X	X							X
C490	20	74	X	X	X						
C498	20	74	X			X	X				
C500	20	73	X		X		X				
C503	20	73	X		X		X				
C504	-	72				X			X		
C510	20	73				X			X		
C515	20	73	X			X			X		
C519	20	73	X			X			X		
C521	20	73	X			X			X		
C522	20	73	X			X			X		

DOPANTS	RADAM#	POLY#	F313	F360	B360	F400	B400	F436	B436	F450	B450
C523	20	73	X			X			X		
C525	20	73	X			X	X	X	X		
C535	20	73	X			X			X		
C540	20	73	X			X			X		
C545	20	73	X			X			X		
CBSTY 3	22	78	X	X	X						
CBSTY 124	22	78	X	X	X						
DASBTI	†	76	X			X	X				
DASPI	†	76	X	X	X						
DCI2	†	76	X			X					
DCM	22	78	X							X	X
DCM2	22	11	X								X
DiACFN	22	77	X								
DiBRFN	22	77	X			X					
DMETCL	22	78	X							X	
DMPOPOP	22	79	X	X	X						
DOCI	22	78	X			X					
DODCI+C-E	22	11	X						X		
DODCI	22	78	X								
DQOCI	22	78	X							X	X
DTCI	22	78	X							X	
DTDCI	22	11	X				X				
F555	-	77	X							X	X
FN548/DiCLFN	22	77	X	X							
HIDCI+C-E	22	11	X				X				
ISCNFN	22	77	X								
KITON RED 620	22	79	X								
LD423	-	77	X	X	X						
LD425	-	77	X	X	X						
LD473	-	77	X			X	X				

DOPANTS	RADAM#	POLY#	F313	F360	B360	F400	B400	F436	B436	F450	B450
LD489	-	77	X			X	X				
LD490	22	77	X			X	X				
LD688	22	11	X		X						
LDS722+C-E	22	11	X		X						
LDS730+C-E	22	11	X		X						
LDS750+C-E	22	11	X		X						
LPY	20	81	X♦								
MALACT GR.+C-E	22	11	X								
NILE BLUE 690+C-E	22	11	X								
OXAZINE 725	22	11	X								
PERYLENE	22	78	X			X	X				
PHENOXAZON 9	*	78	X							X	X
PYRIDIN1	22	78	X			X					
PYRONIN B	*	79	X								
RHODAMINE 6G	22	79	X								
RHODAMINE575	22	79	X								
STILBENE 420	22	79	X								

C-E = A crown-ether added as solubilizing agent
* Samples were too opaque to be irradiated
† Samples do not show any fluorescence.
♦LPY was measured with a BS 313.

APPENDIX C: TABLE OF SPECTROSCOPIC CHARACTERISTICS

DOPANTS	ABS. RANGE (nm)	FS EMISSION (nm)	BS EMISSION (nm)	LIFETIME (ns)	BRIGHTNESS (%)
K27	300-480	468,496,530	496,530	11.8	100*
ACRIDINE O B	300-500	520	-	Insufficient Light Output	
ACRIDINE Y	300-560	none	none	No Light Output	
ACRIFLAVINE	300-360	none	none	No Light Output	
BBOT	300-420	414,436460	436,462	-	-
bis-MSB	300-410	406,426	428	-	-
BSFL	300-480	none	none	No Light Output	
C4	300-360	368	-	Insufficient Light Output	
C35/C481	300-450	456	460	9.1	95
C138	300-400	406	410	Short wavelength emission	
C153K/C153LP	300-470	478	480	10.8	99
C311	300-400	408	410	Short wavelength emission	
C314T	300-460	456	468	9.6	106
C338	300-460	460	472	9.7	105
C339	300-410	408	414	Short wavelength emission	
C440	300-390	394	396	Short wavelength emission	
C445	300-390	402	402	Short wavelength emission	
C450	300-400	402	404	Short wavelength emission	
C460	300-410	410	414	Short wavelength emission	
C466/LD466	300-420	416	420	Short wavelength emission	
C478	300-420	422	428	6.9	65
C480	300-430	424	428	7.2	63
C485	300-450	452	456	9.3	107
C487	300-420	426	430	7.2	62
C490	300-420	426	430	6.9	52

DOPANTS	ABS. RANGE (nm)	FS EMISSION (nm)	BS EMISSION (nm)	LIFETIME (ns)	BRIGHTNESS (%)
C498	300-470	456	470	9.5	109
C500	300-440	440	444	8.0	85
C503	300-440	442	446	8.1	88
C504	300-470	458	468	8.5	-
C510	300-480	478	484	7.6	119
C515	300-480	478	492	7.5	100
C519	300-490	474	488	10.0	100
C521	300-490	476	490	10.3	106
C522	300-460	466	472	9.4	113
C523	300-490	470	484	10.0	95
C525	300-520	508	518	8.1	82
C535	300-500	504	508	7.7	85
C540	300-510	510	514	7.4	90
C545	300-520	526	528	8.4	76
CBSTY 3	300-390	366,392	396	Short wavelength emission	
CBSTY 124	300-380	366,388	390	Short wavelength emission	
DASBTI	300-460	474	474	Insufficient Light Output	
DASPI	300-420	440	442	Insufficient Light Output	
DCI2	300-660	474	-	Insufficient Light Output	
DCM/DCM2	300-530	558,584	562,582	Insufficient Light Output	
DiACFN	-360	none	none	No Light Output	
DiBRFN	300-440	514	-	Insufficient Light Output	
DMETCI	300-490	none	none	No Light Output	
DMPOPOP	300-420	408,430	430	-	-
DOCI	300-460	none	none	No Light Output	
DODCI	300-460	none	none	No Light Output	
DQOCI	300-580	none	none	No Light Output	
DTCI	300-500	none	none	No Light Output	

DOPANTS	ABS. RANGE (nm)	FS EMISSION (nm)	BS EMISSION (nm)	LIFETIME (ns)	BRIGHTNESS (%)
DTDCI	300-540	none	none	No Light Output	
F555	300-480	494	496	-	-
FN548/DiCLFN	300-520	none	none	No Light Output	
HIDC IODIDE	300-570	none	none	No Light Output	
ISCNFN	300-330	none	none	No Light Output	
KITON RED 620	300-380	none	none	No Light Output	
LD 423	300-400	398	402	Short wavelength emission	
LD 425	300-390	404	406	Short wavelength emission	
LD 473	300-430	434	436	-	-
LD 489	300-450	452	454	-	-
LD 490	300-430	434	438	-	-
LD 688	300-600	584	586	Insufficient Light Output	
LDS 722	300-590	none	none	No Light Output	
LDS 730	300-600	384,424	430	Insufficient Light Output	
LDS 750	300-400	none	none	No Light Output	
LPY	300-510	-	506	6.9	89
MALACHITE GR	300-510	none	none	No Light Output	
NILE BLUE	300-700	none	none	No Light Output	
OXAZINE 725	300-720	none	none	No Light Output	
PERYLENE	300-450	452,476,508	476,508	-	-
PHENOXAZON 9	300-600	572,584	612	Insufficient Light Output	
PYRIDIN 1	300-380	none	none	No Light Output	
PYRONIN B	300-760	none	none	No Light Output	
RHODAMINE 6G	300-370	none	none	No Light Output	
RHODAMINE 575	300-350	none	none	No Light Output	
STILBENE 420	-320	none	none	No Light Output	

*All brightness data relative to K27
FS = Front Surface
BS = Back Surface

Fermi National Accelerator Laboratory

FERMILAB-TM-1873

Final Results from the SDC Dopant Search for New Green Wavelength Shifting (WLS) Fibers VOLUME II

A. Pla-Dalmau, G.W. Foster and G. Zhang

Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

December 1993

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FERMILAB-TM-1873

Final Results from the SDC Dopant Search for New Green Wavelength Shifting (WLS) Fibers

VOLUME II

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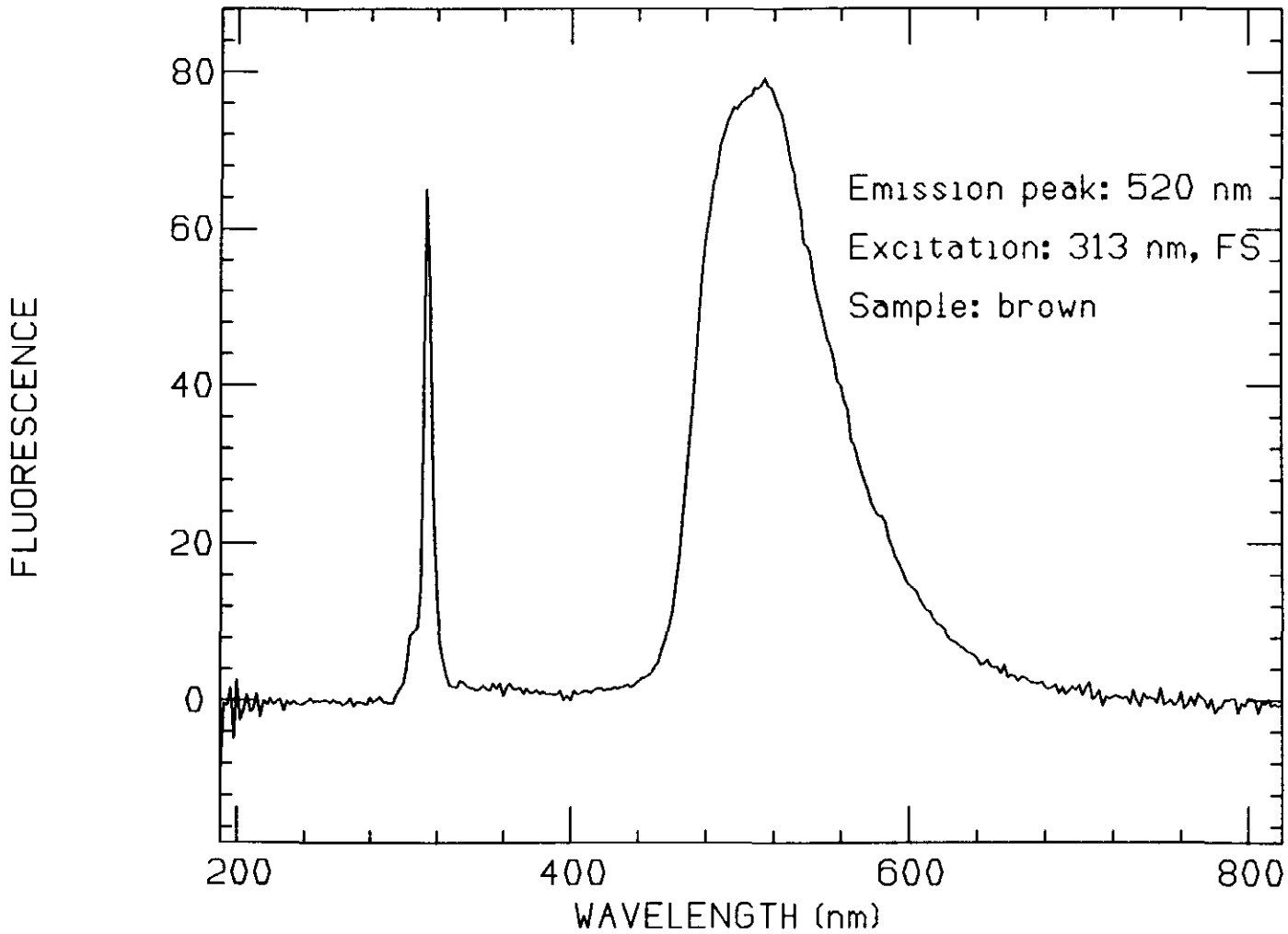
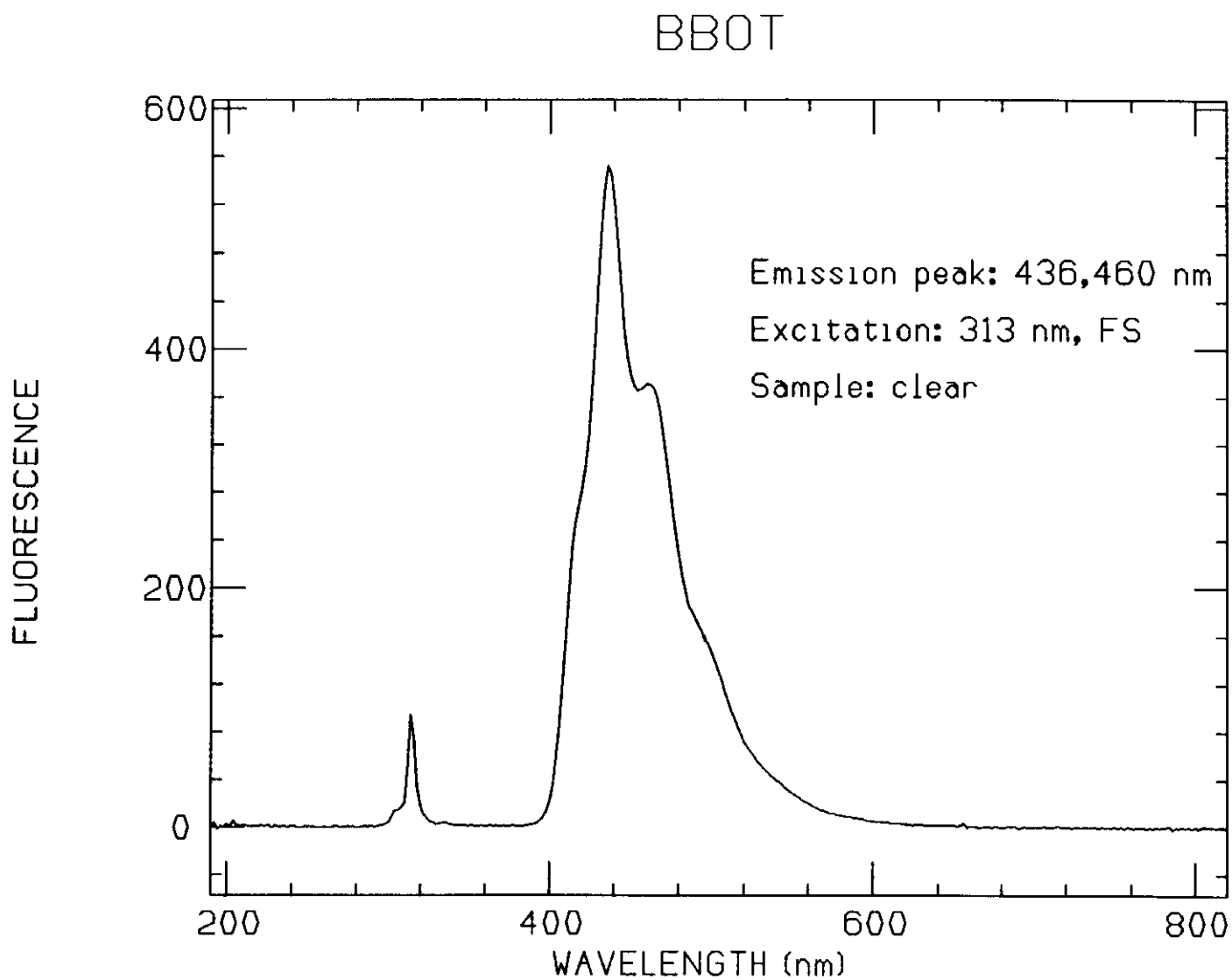
Fermi National Accelerator Laboratory
P. O. Box 500, Batavia, IL 60510, USA

December 13, 1993

TABLE OF CONTENTS

ACRIDINE ORANGE BASE

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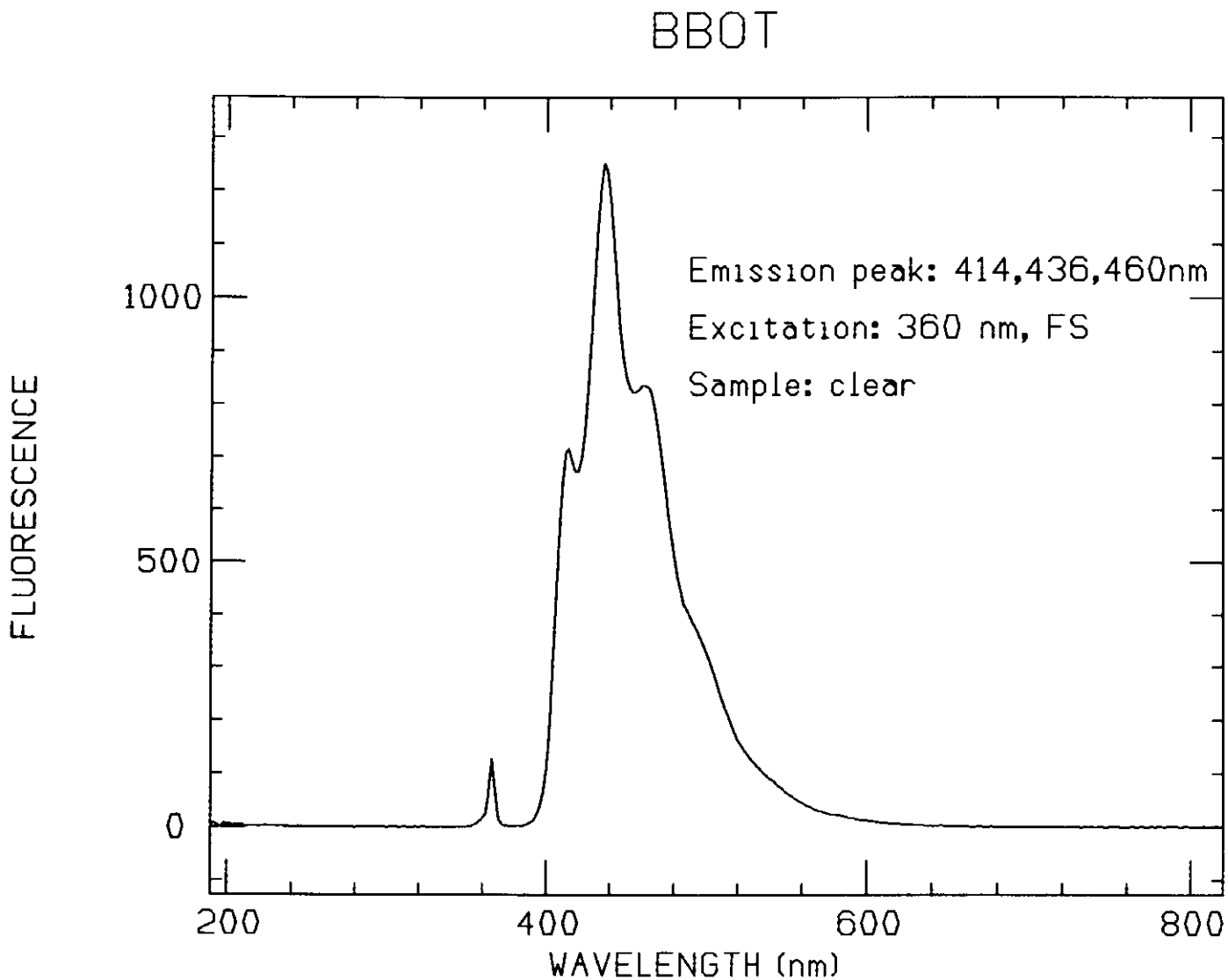
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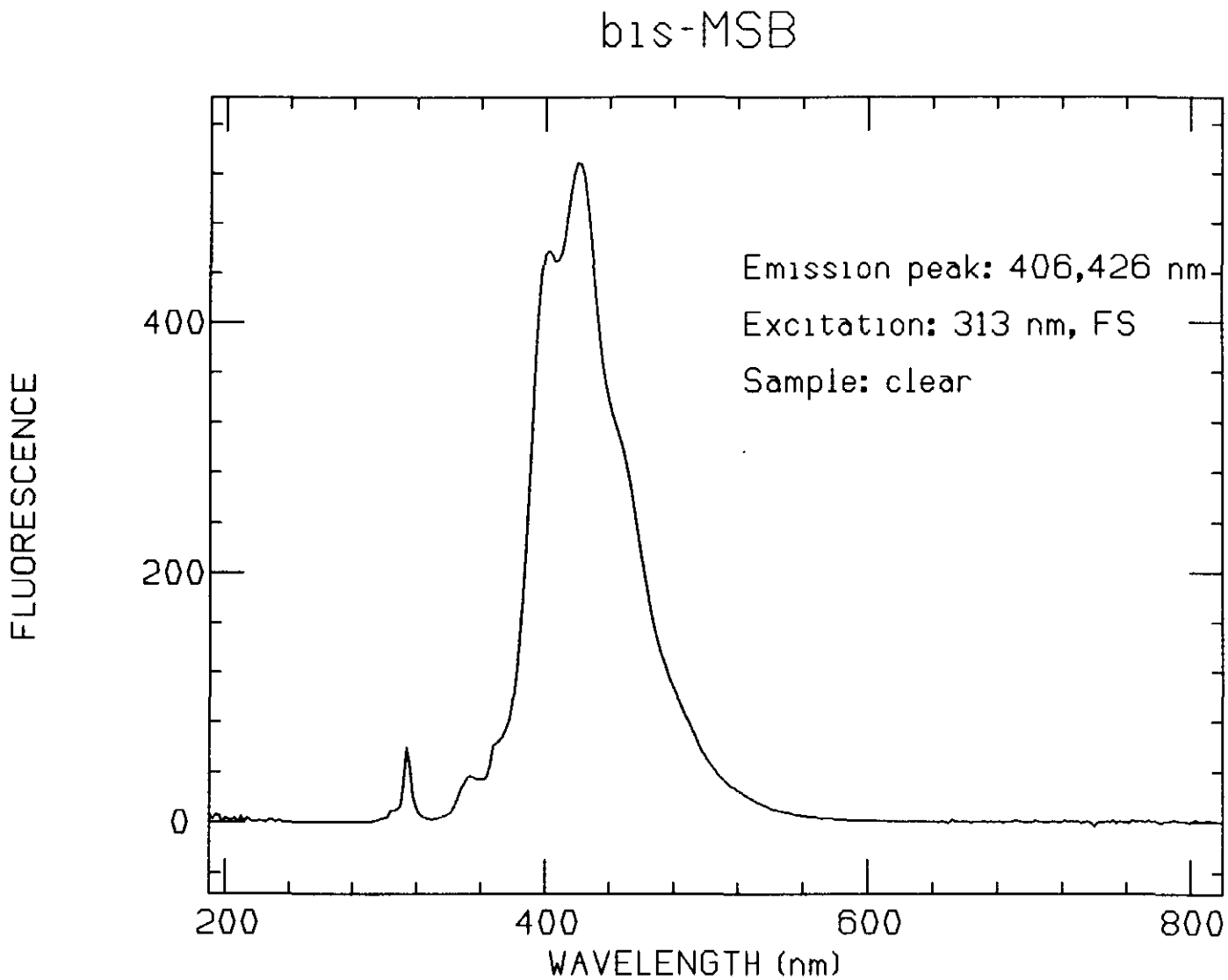
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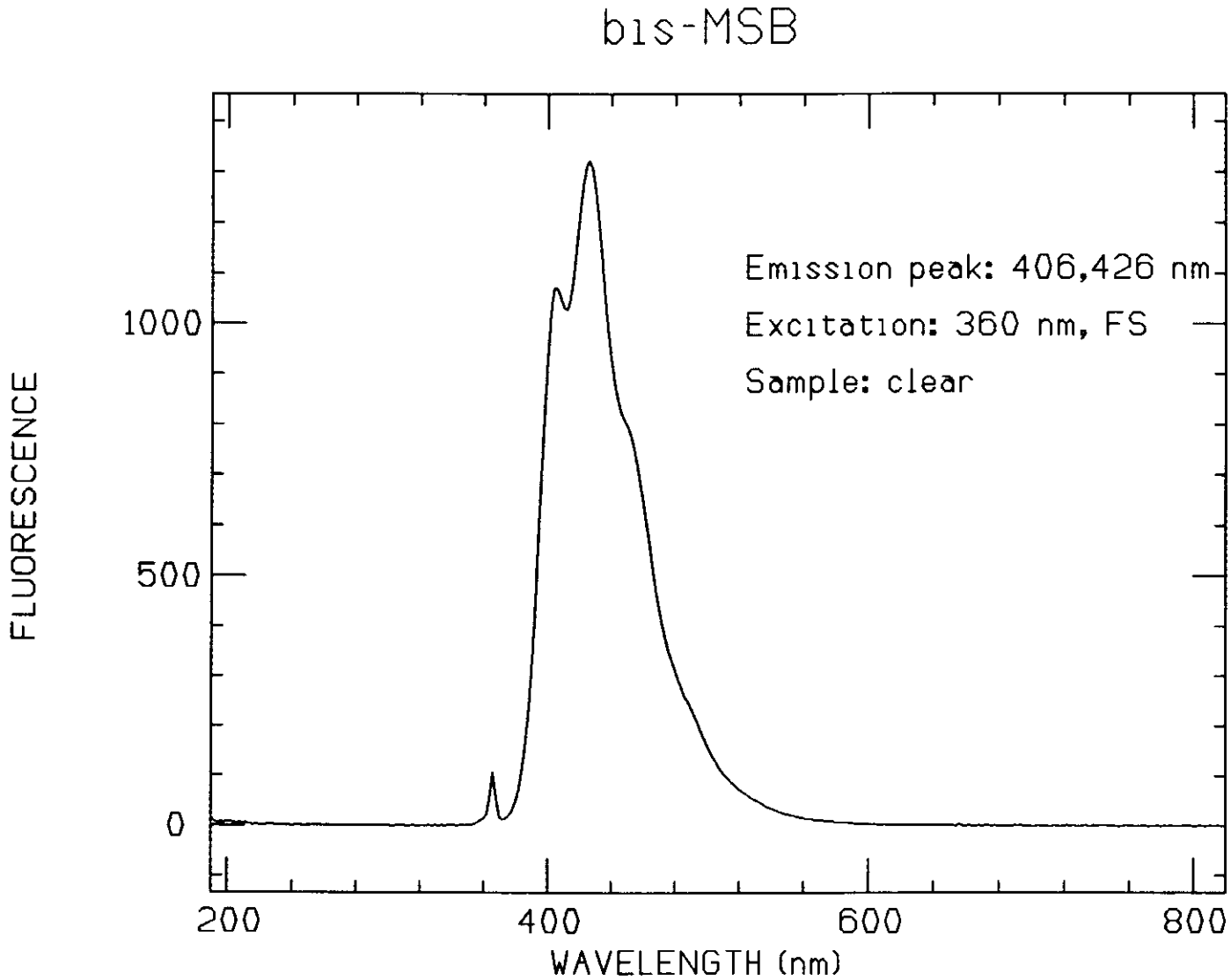
WAVELENGTH (nm)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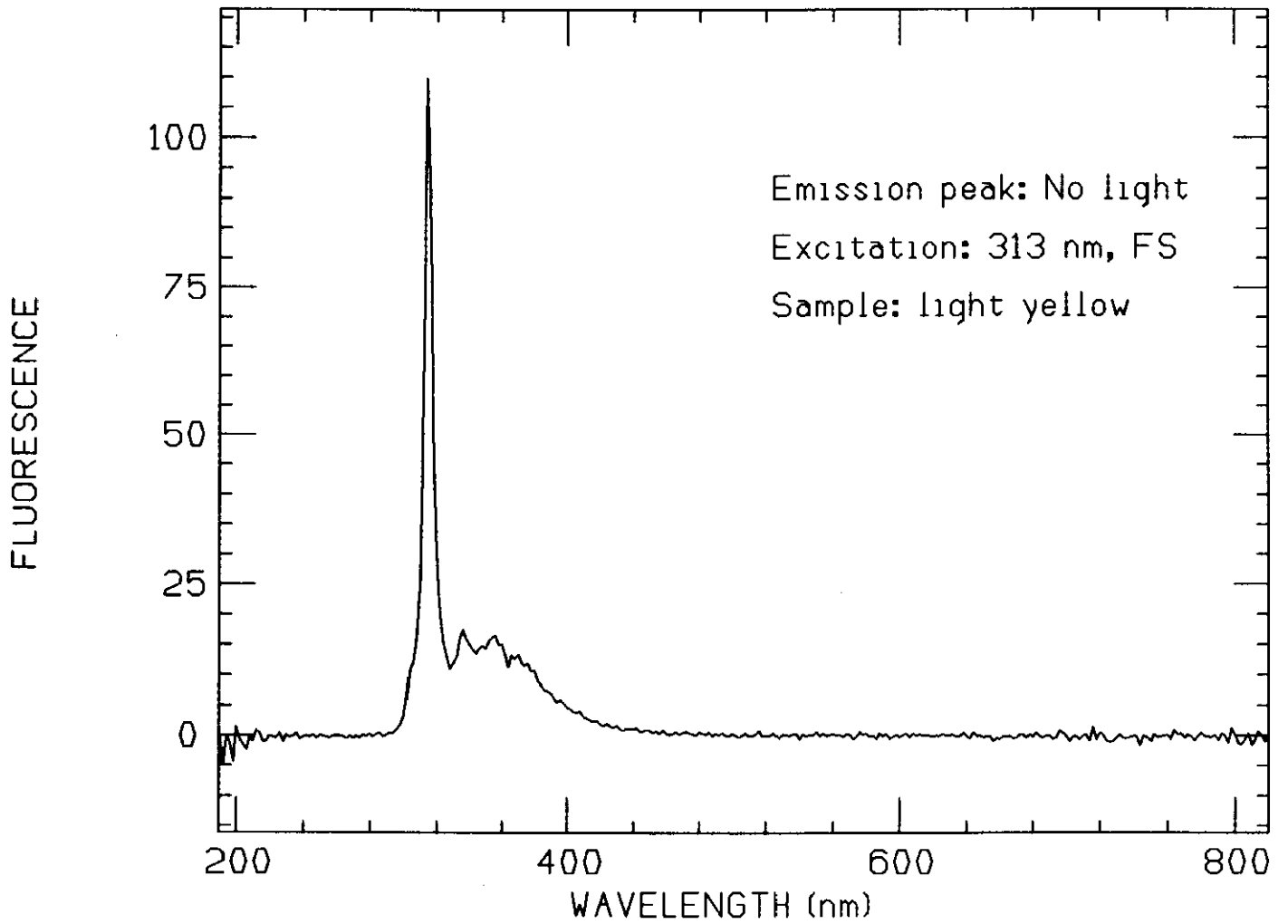
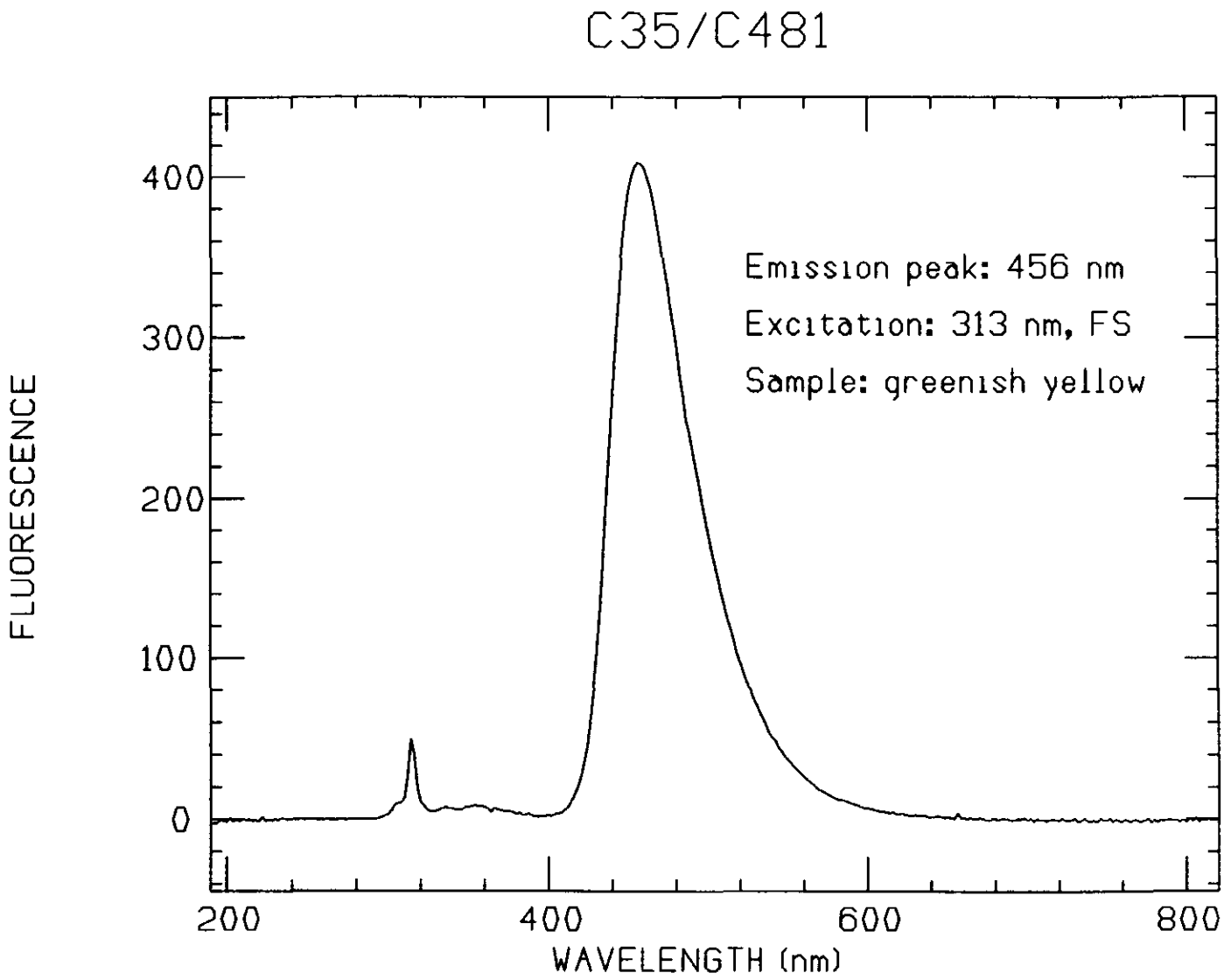
WAVELENGTH (nm)

BRILLIANT SULFAFLAVIN

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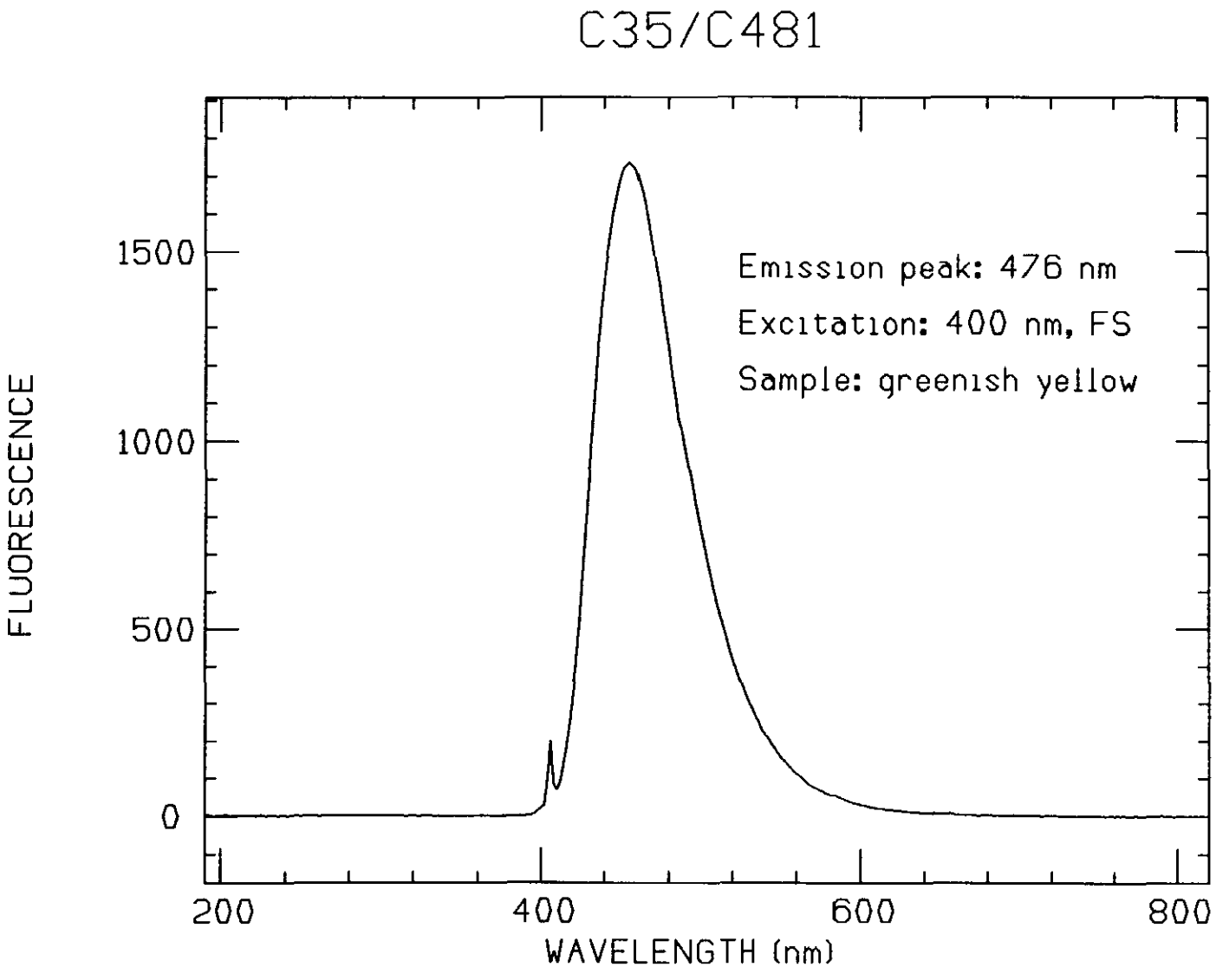
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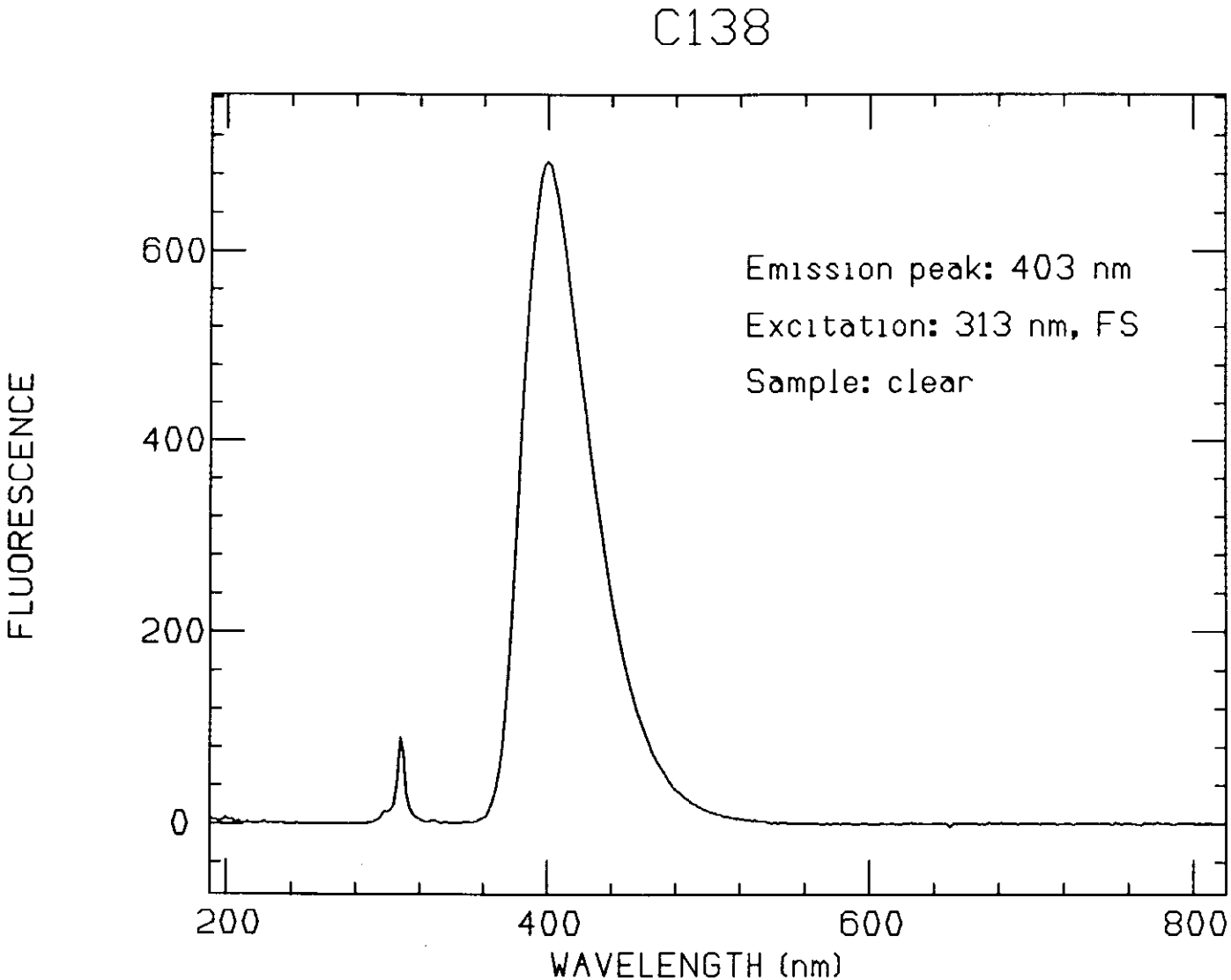
Sample: greenish yellow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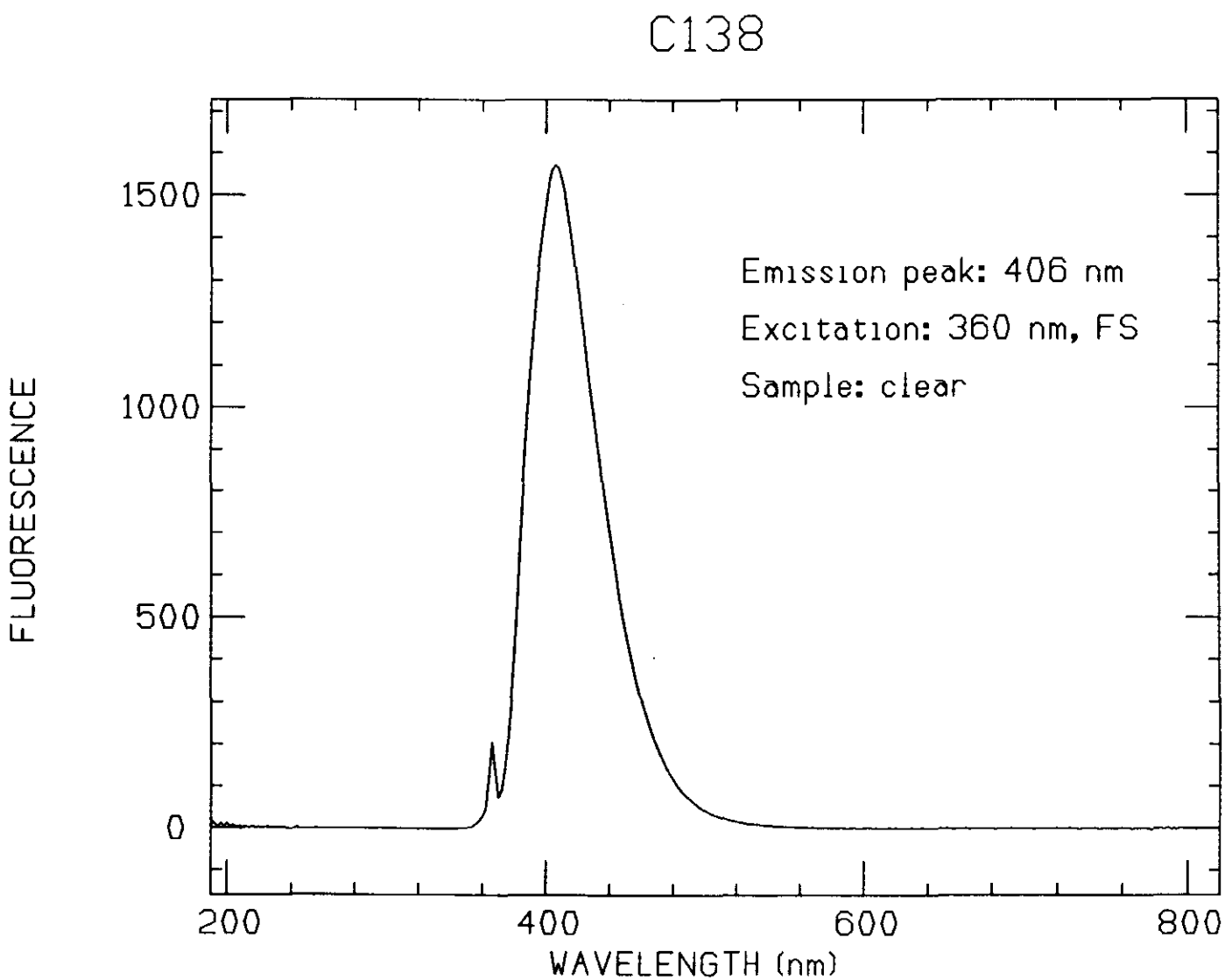
Sample: clear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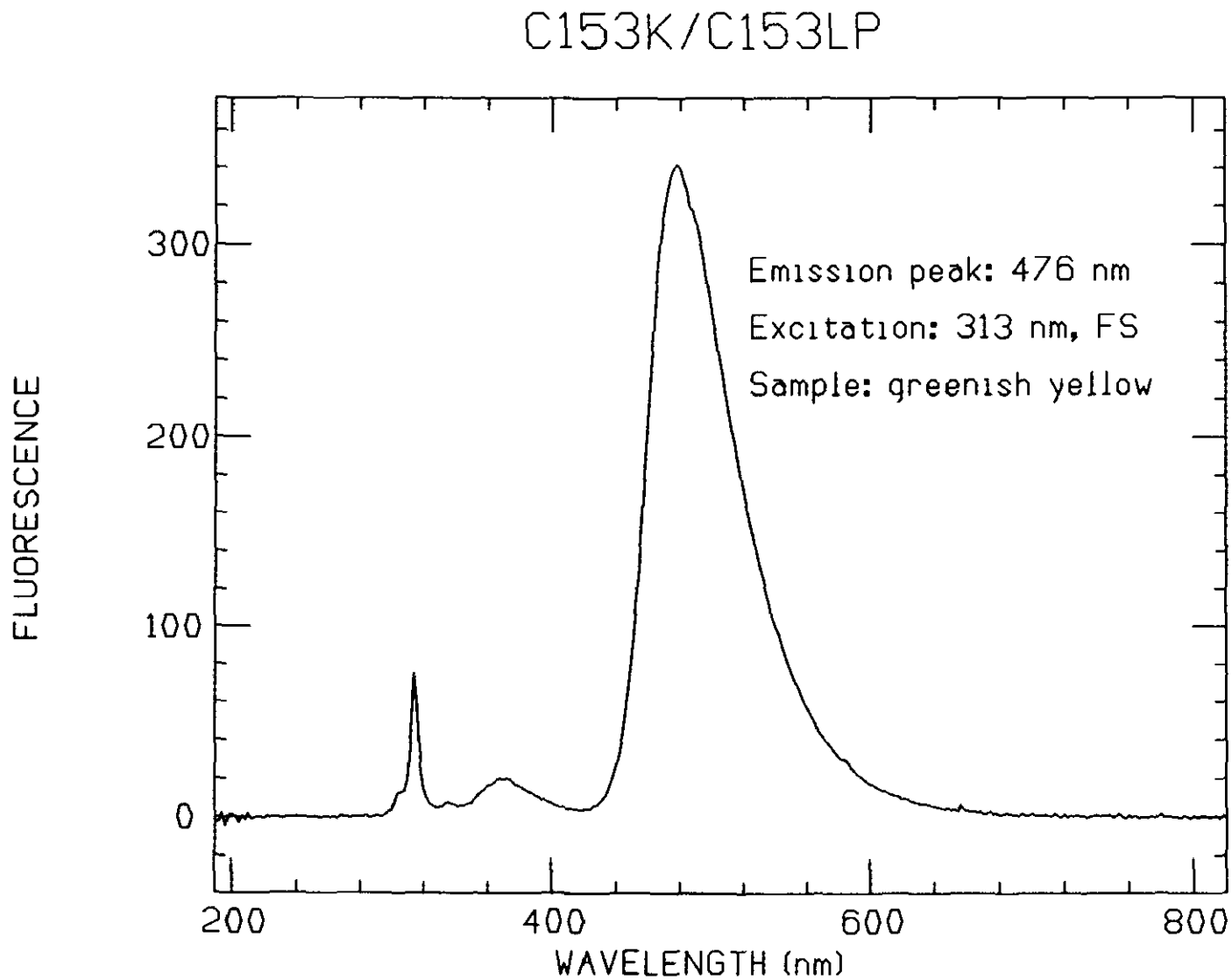
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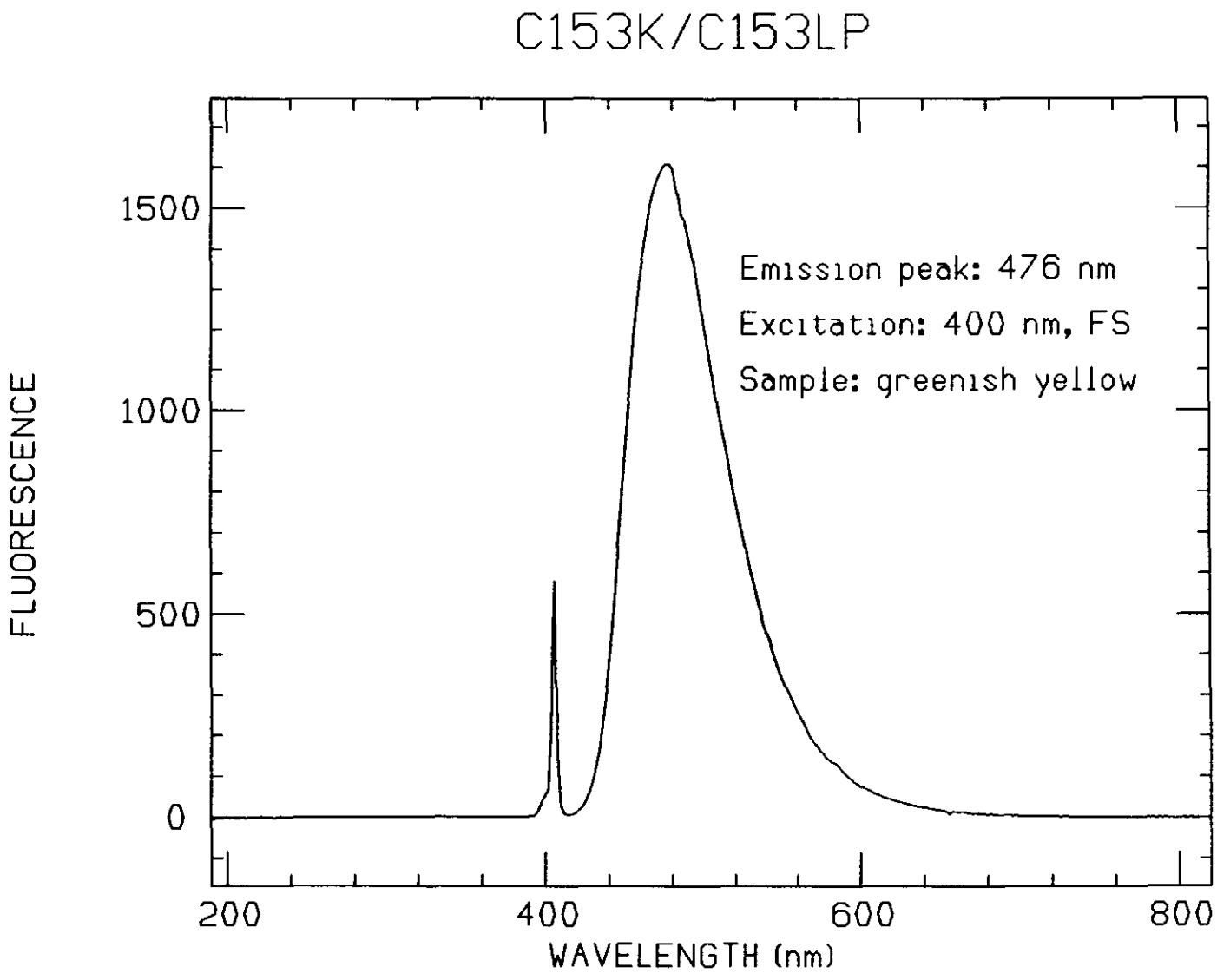
Sample: greenish yellow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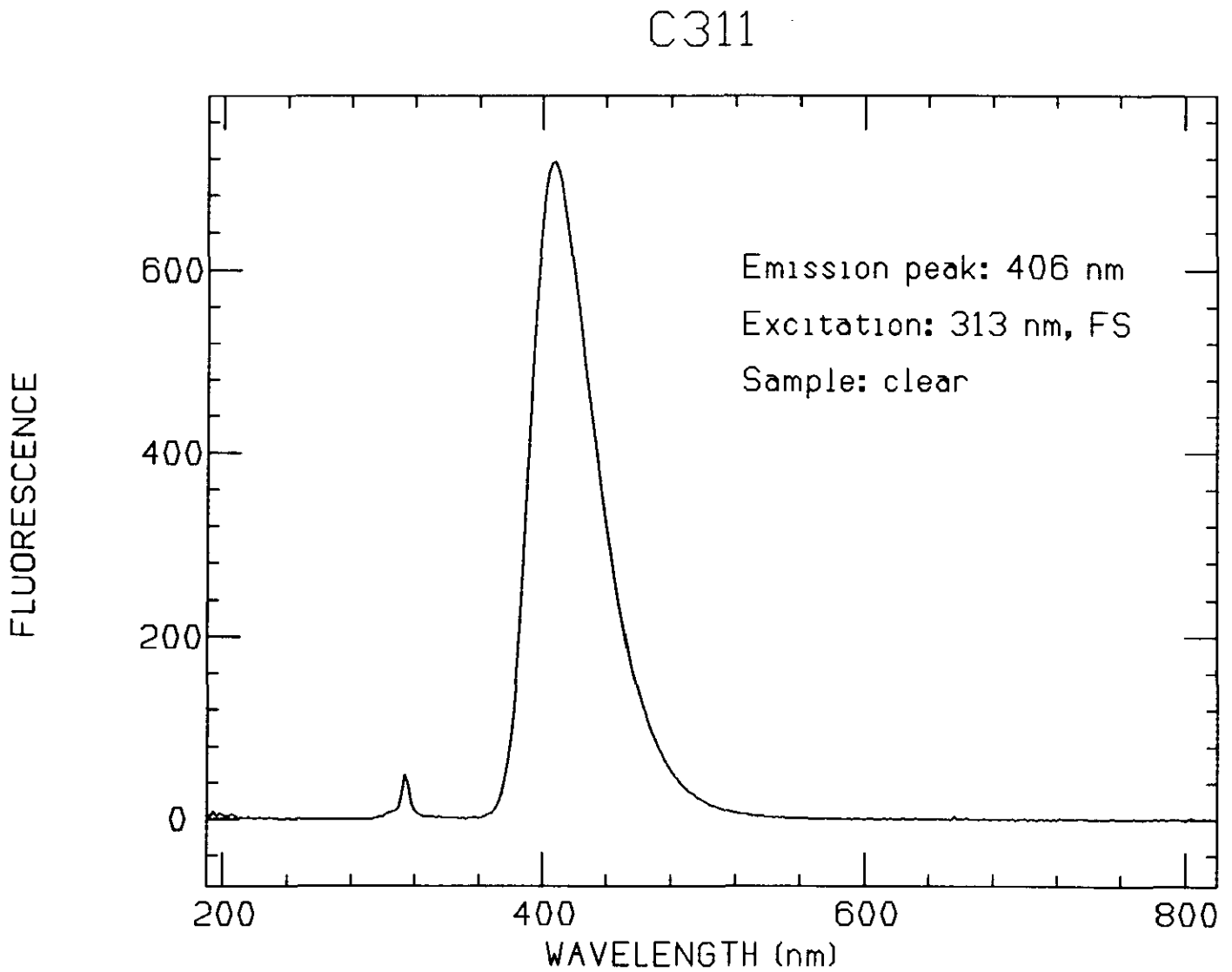
Sample: greenish yellow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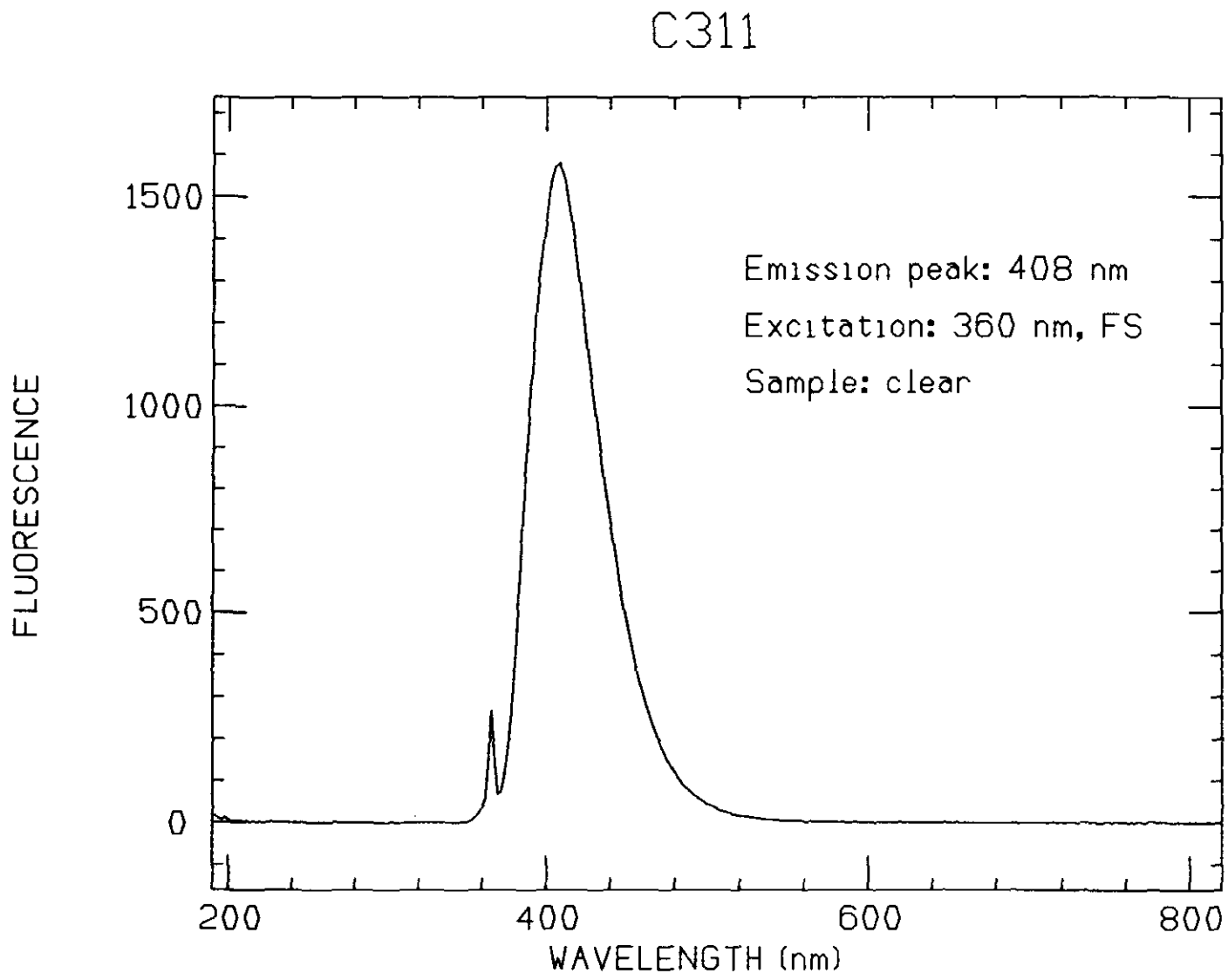
Sample: clear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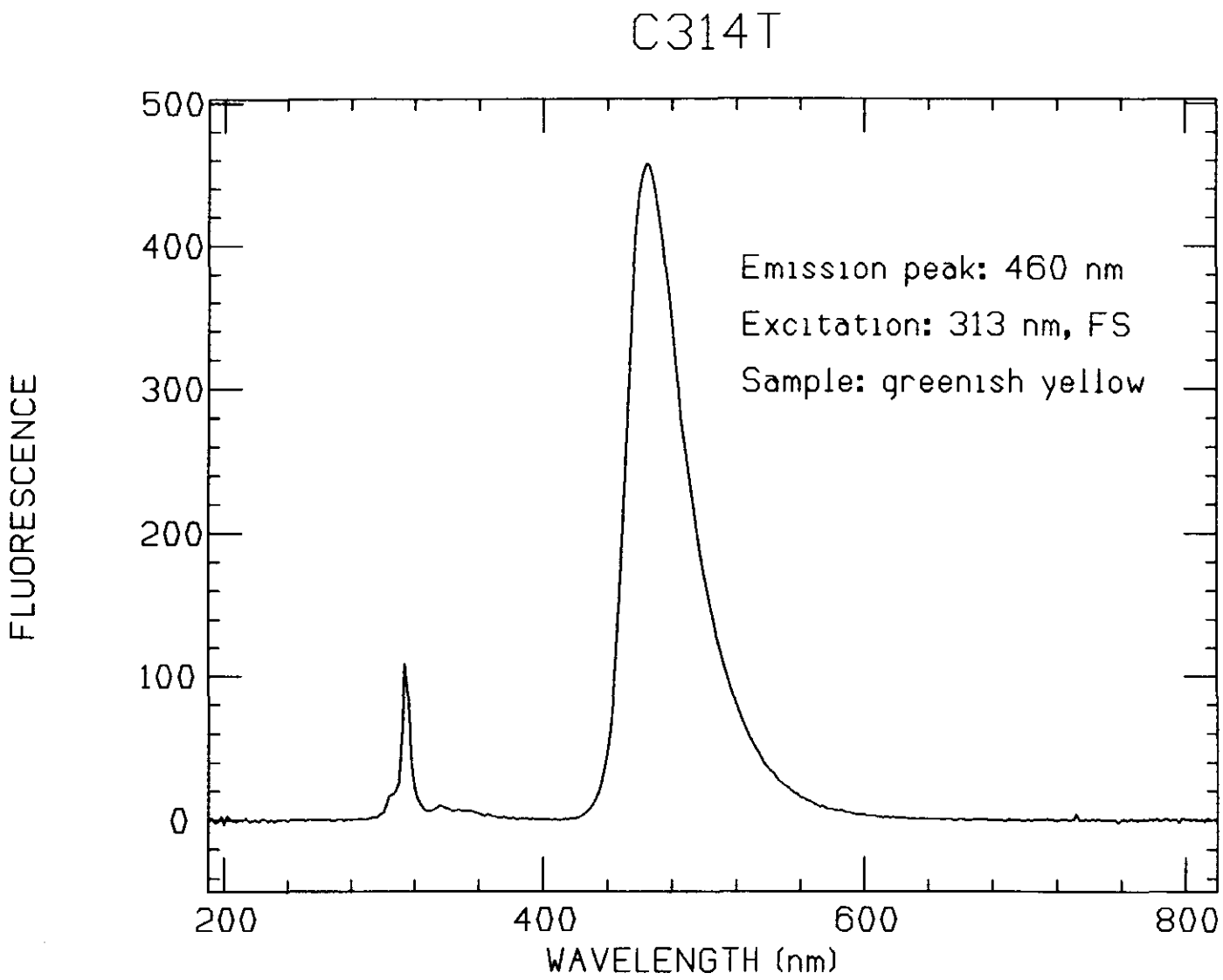
Sample: clear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400
600
800
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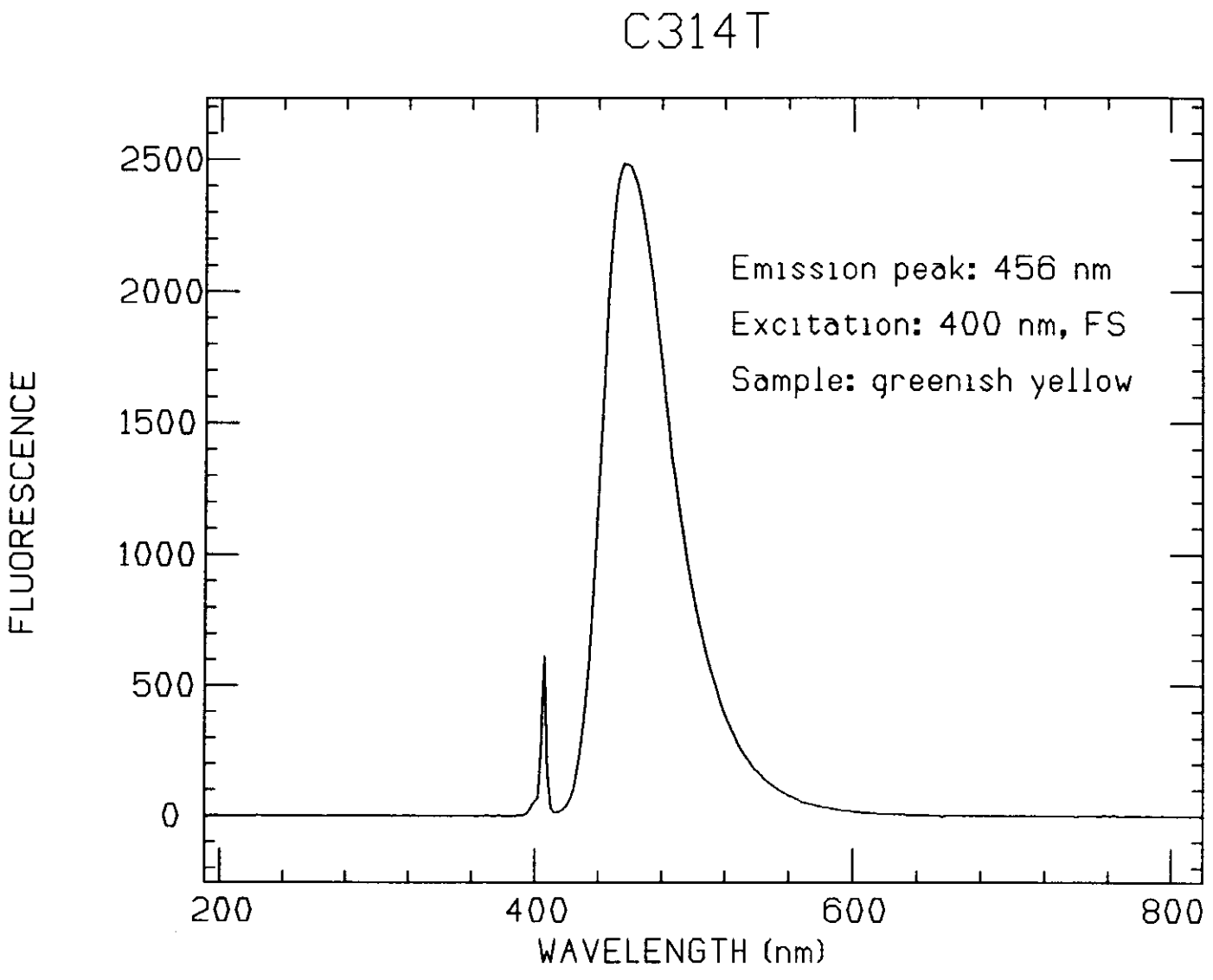
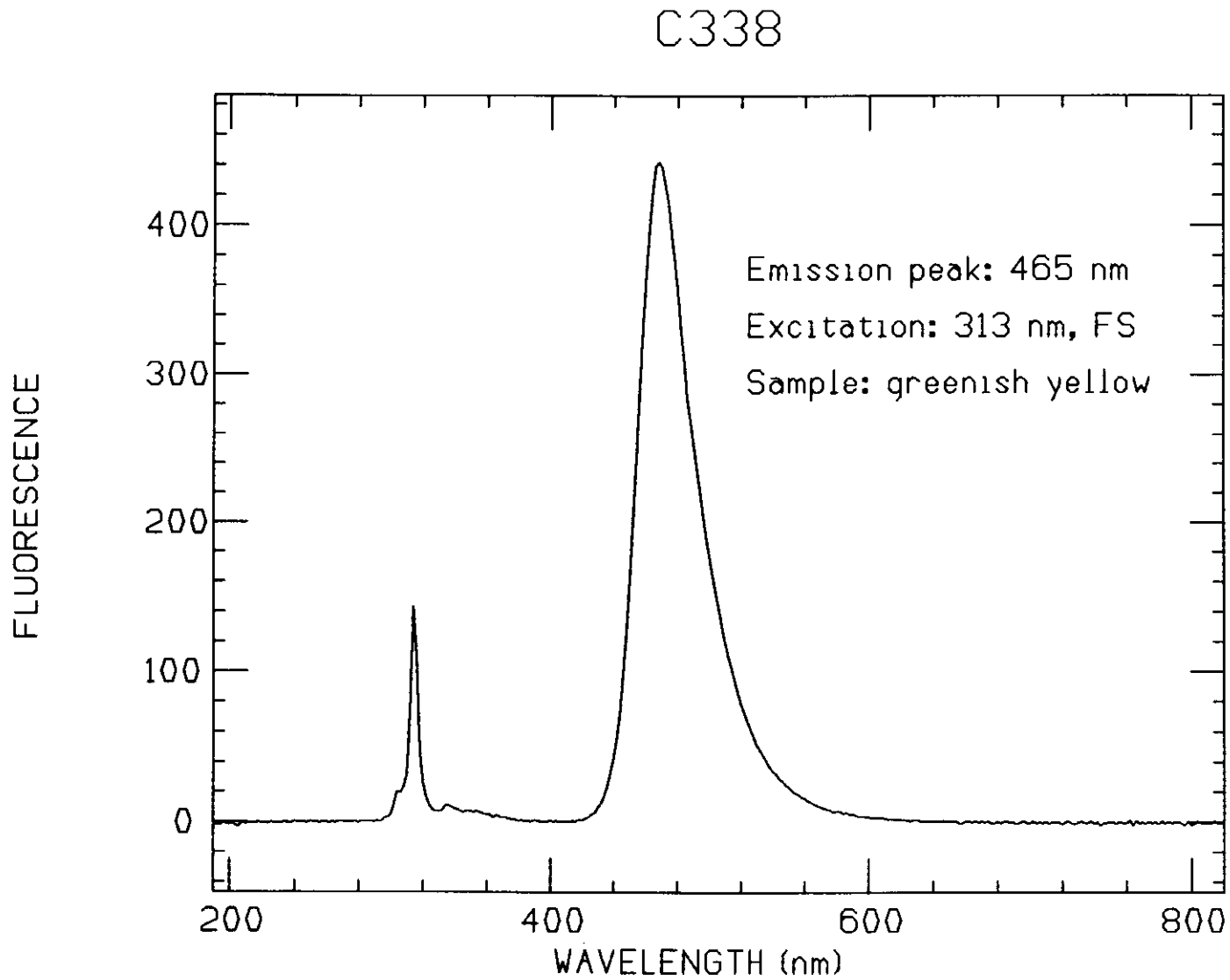
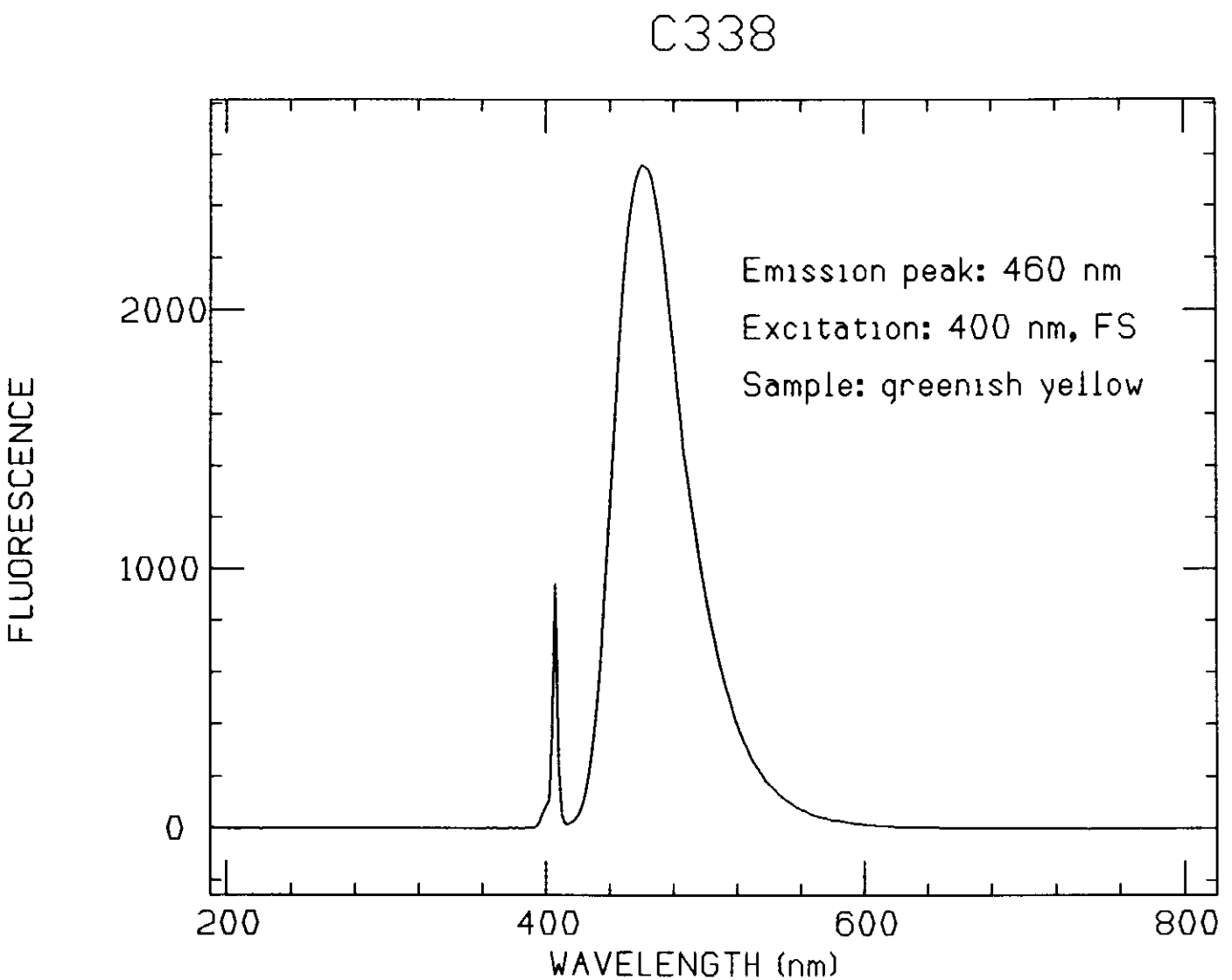
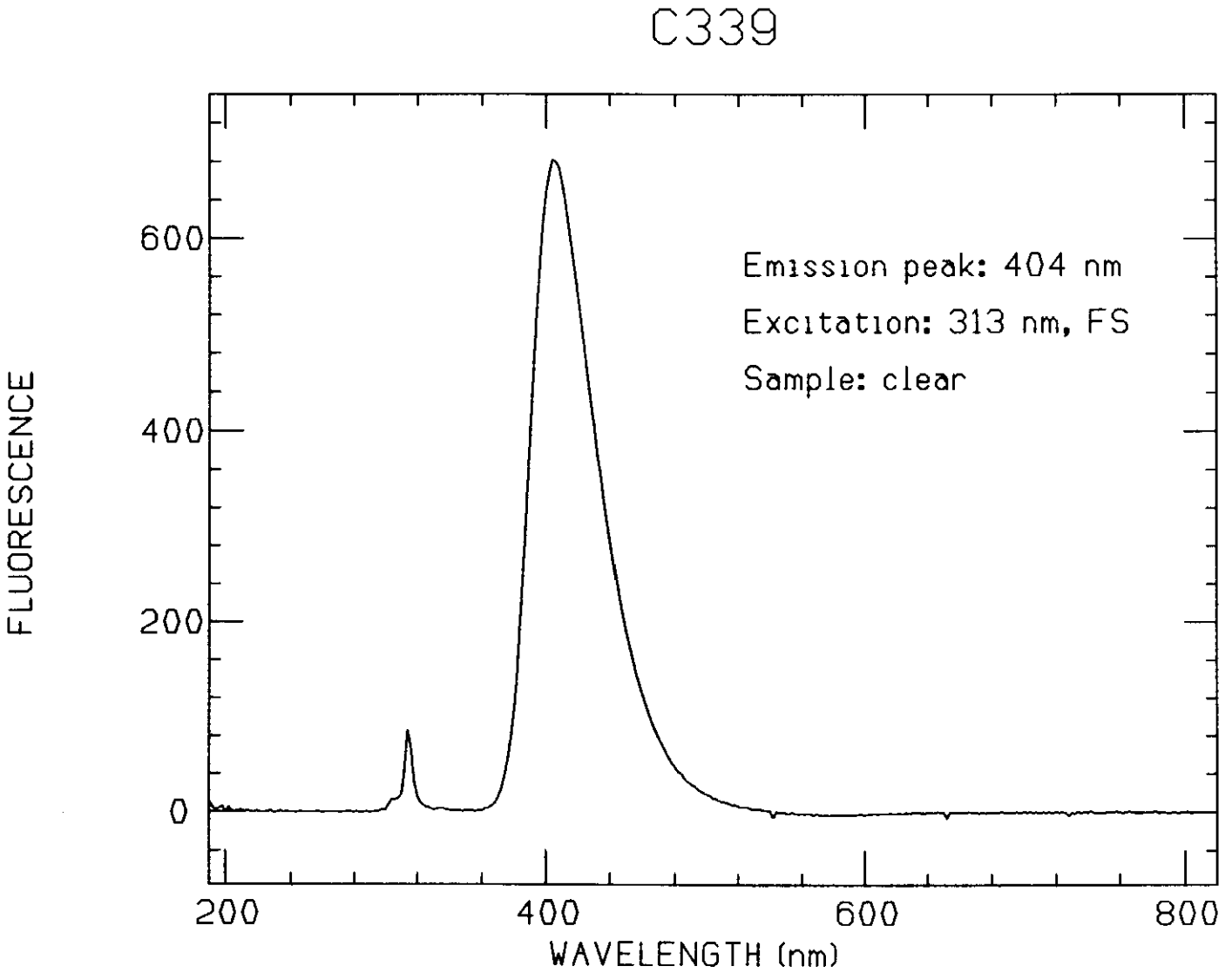
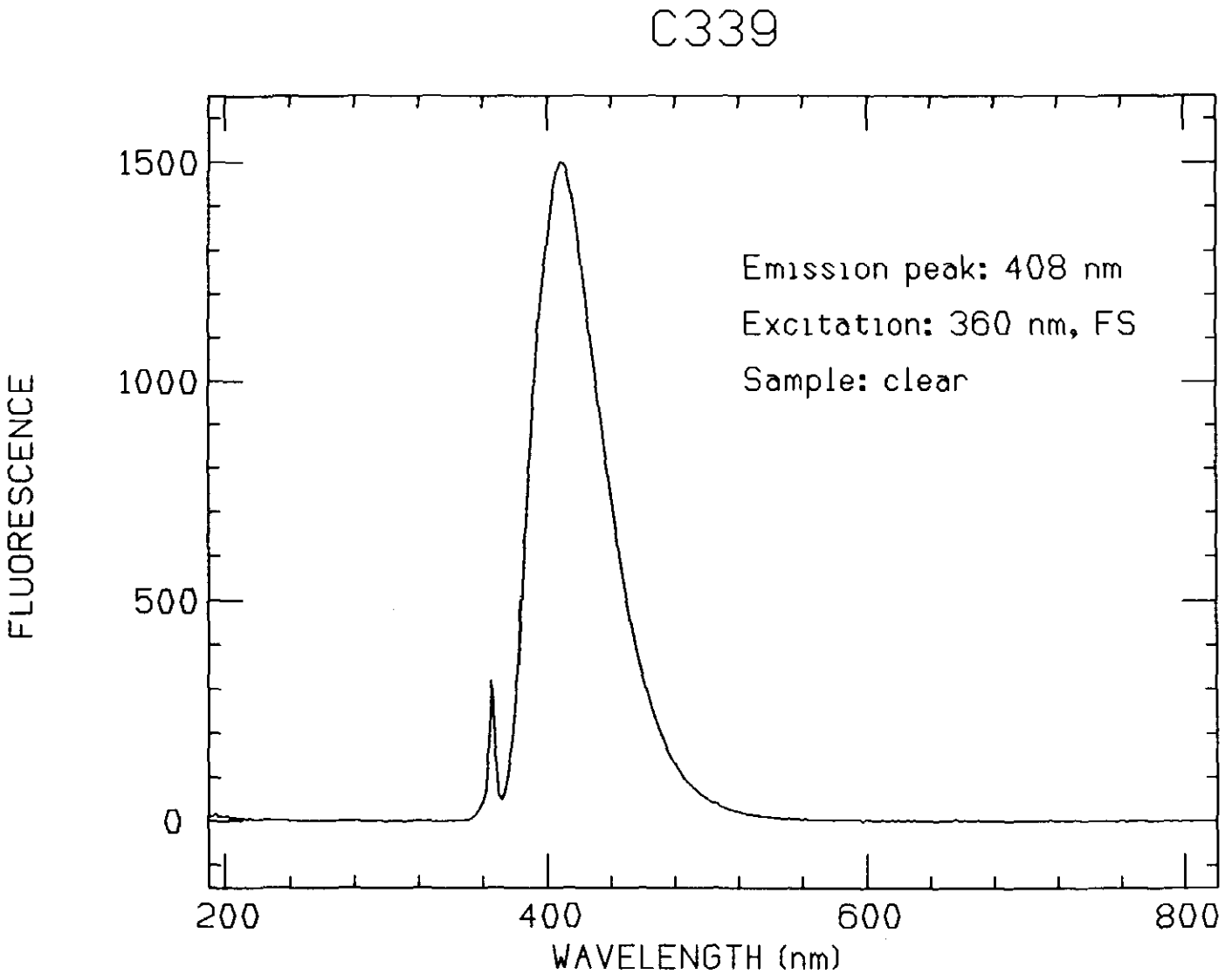
Emission peak: 460 nm
Excitation: 313 nm, FS
Sample: greenish yellow

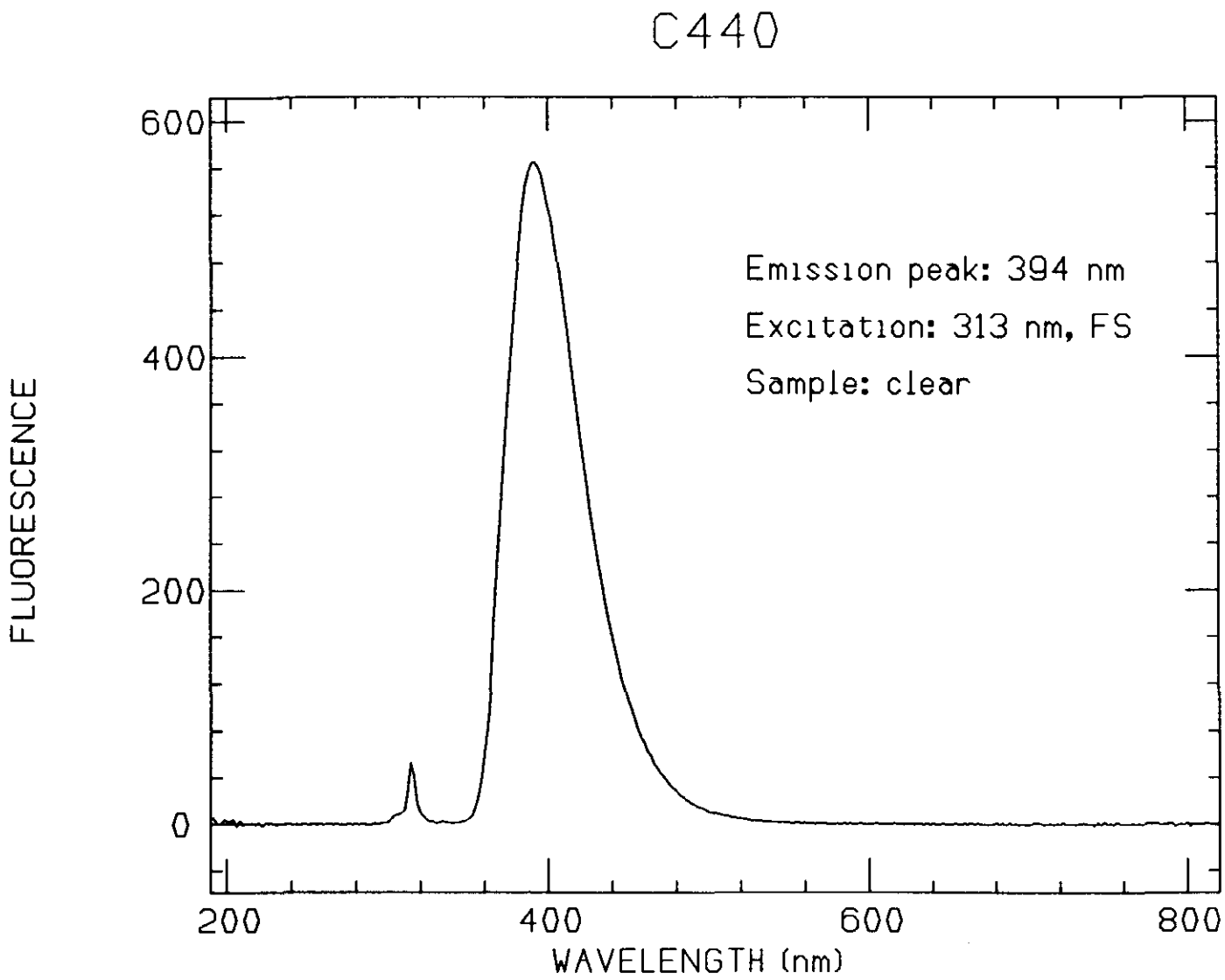

C314T
FLUORESCENCE
2500
2000
1500
1000
500
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 456 nm
Excitation: 400 nm, FS
Sample: greenish yellow

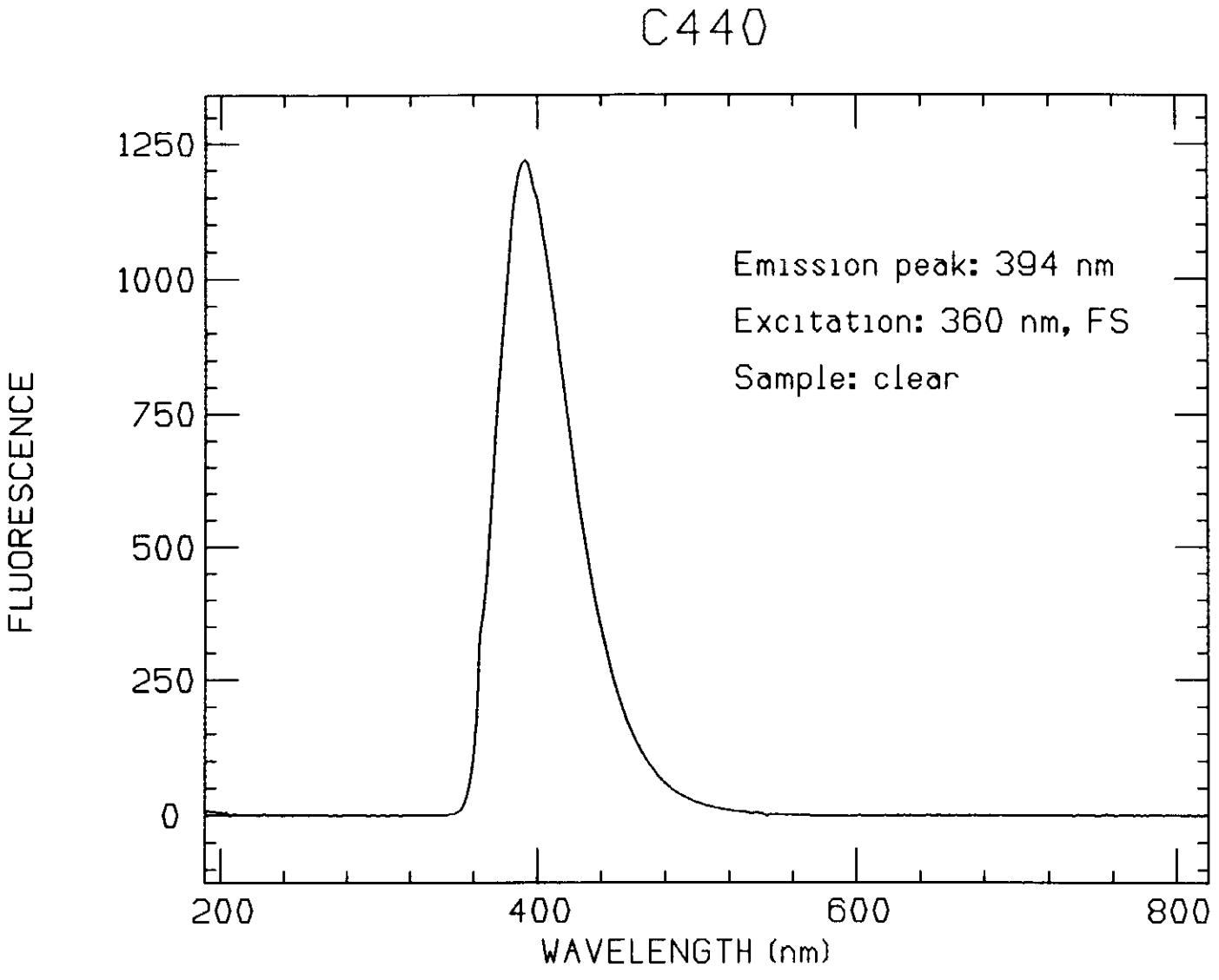

C338
FLUORESCENCE
400
300
200
100
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 465 nm
Excitation: 313 nm, FS
Sample: greenish yellow

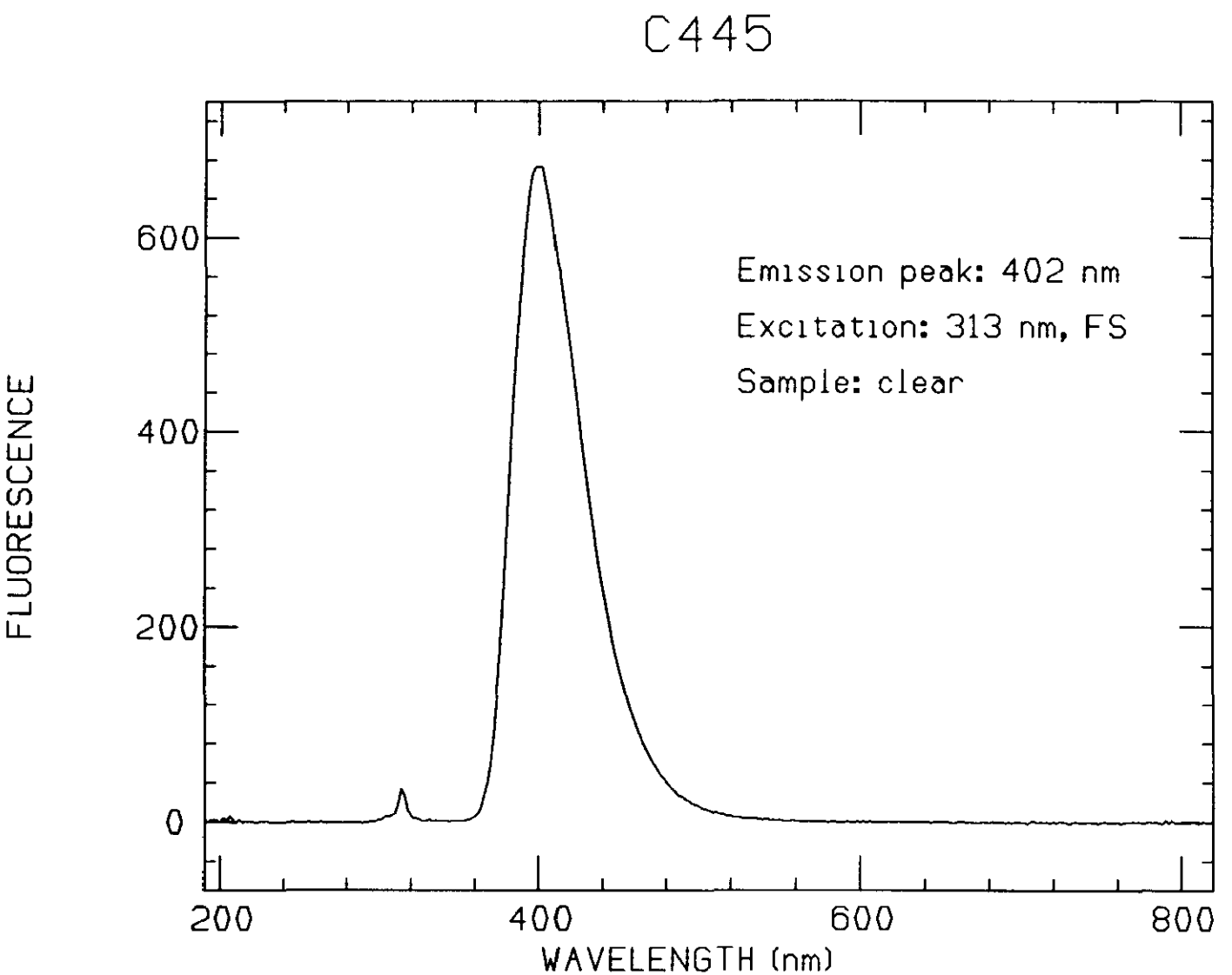

C338
Emission peak: 460 nm
Excitation: 400 nm, FS
Sample: greenish yellow
FLUORESCENCE
2000
1000
0
200
400
600
800
WAVELENGTH (nm)

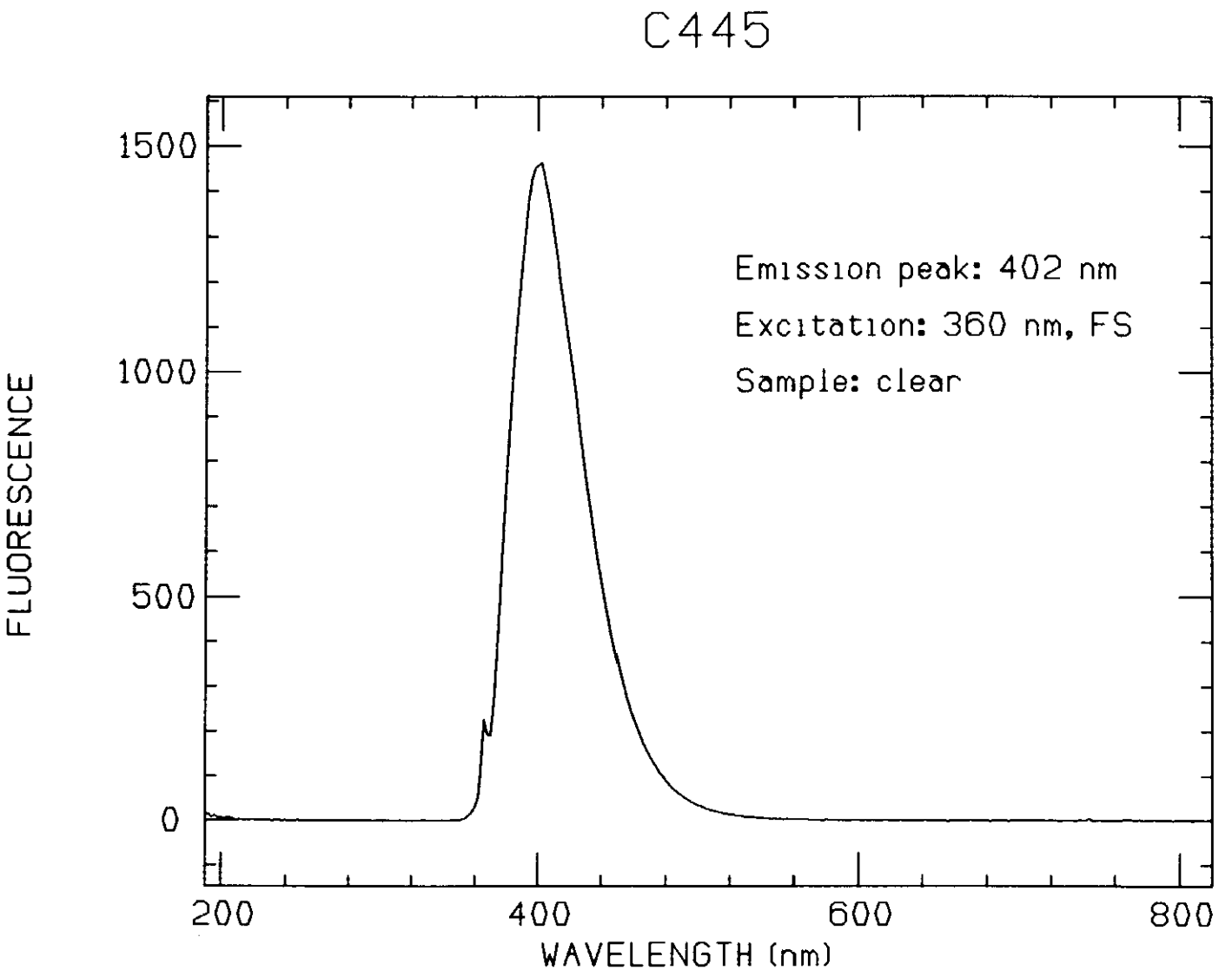

C339
FLUORESCENCE
600
400
200
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 404 nm
Excitation: 313 nm, FS
Sample: clear

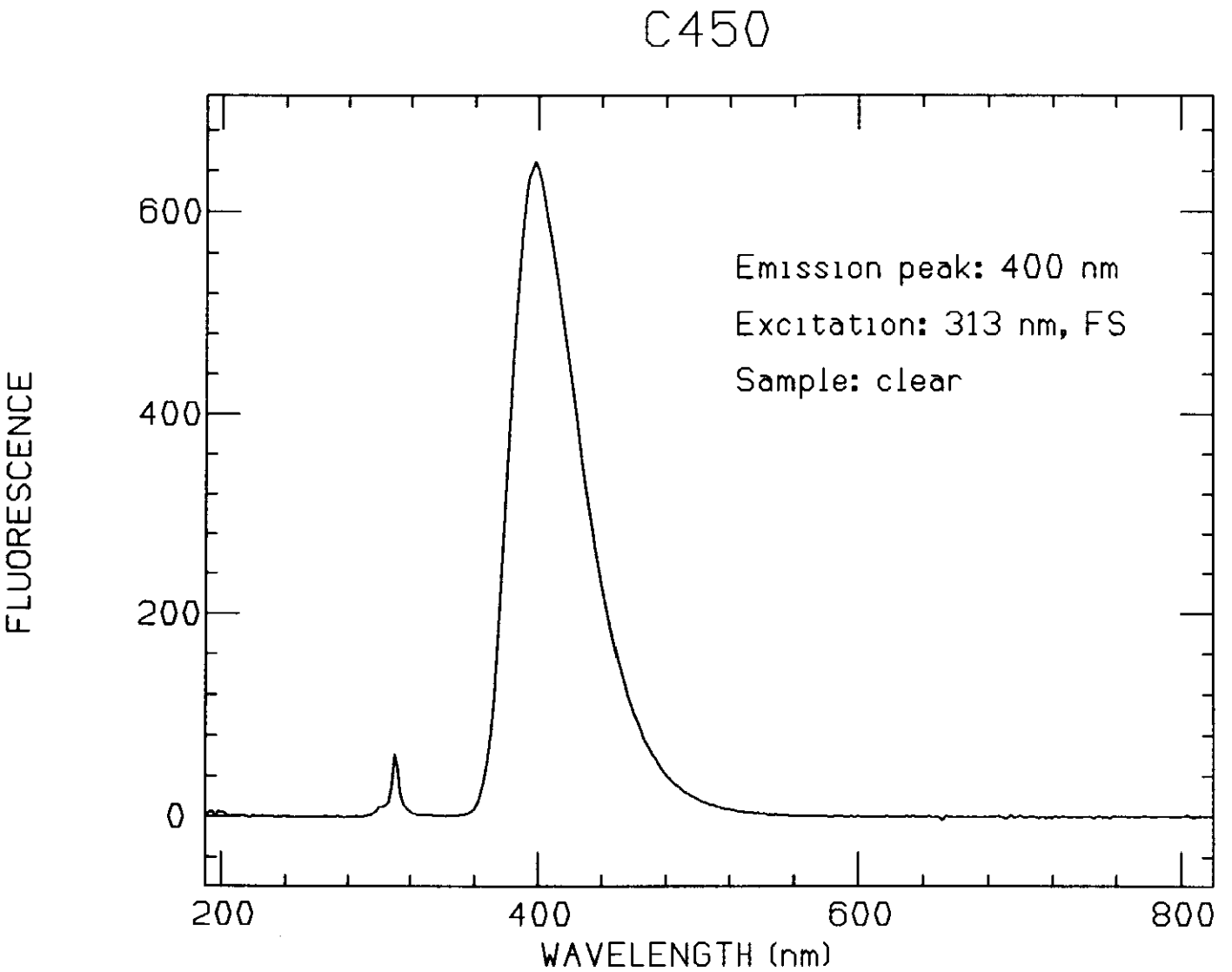

C339
FLUORESCENCE
1500
1000
500
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 408 nm
Excitation: 360 nm, FS
Sample: clear

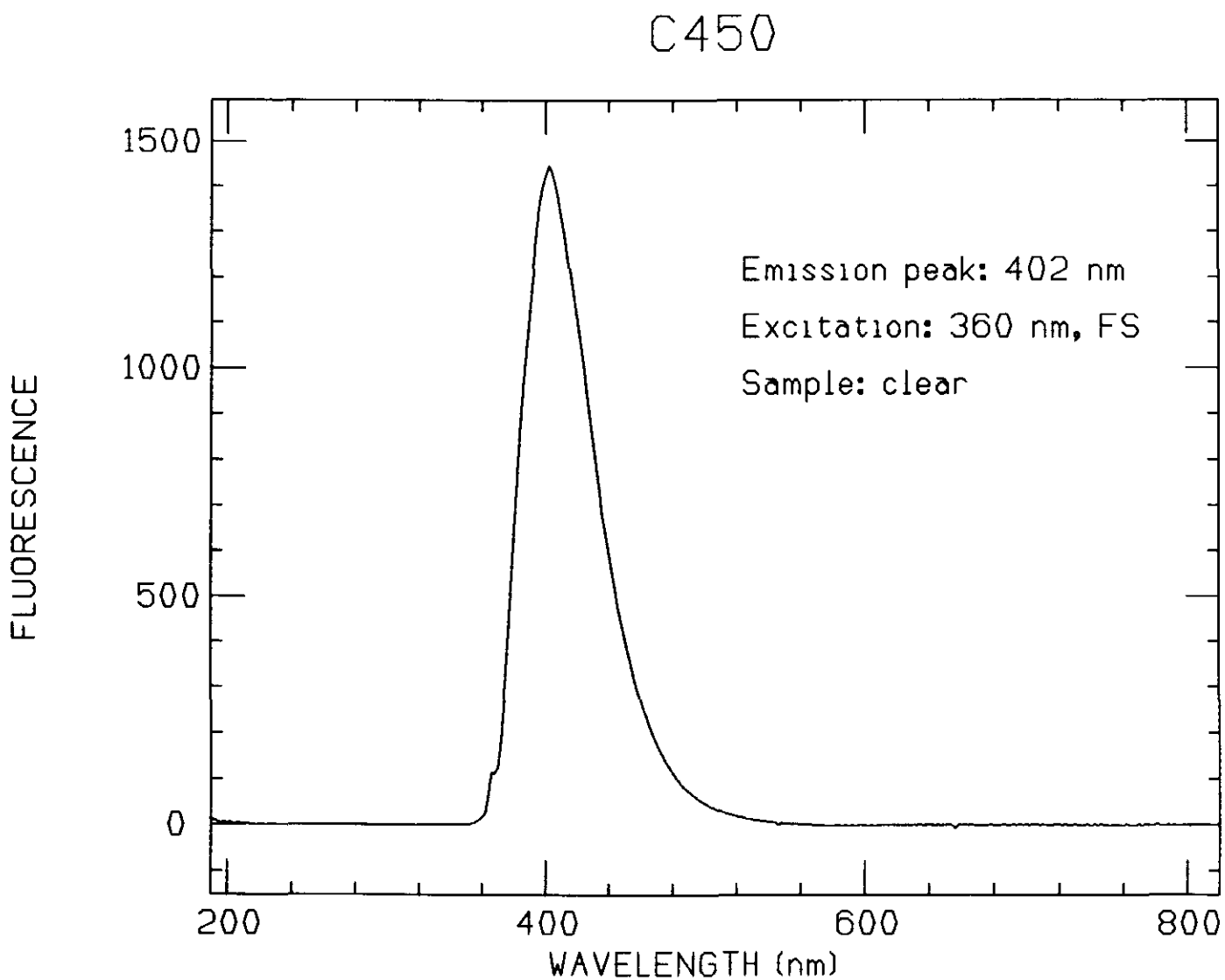

C440
600
400
200
0
FLUORESCENCE
Emission peak: 394 nm
Excitation: 313 nm, FS
Sample: clear
200
400
600
800
WAVELENGTH (nm)

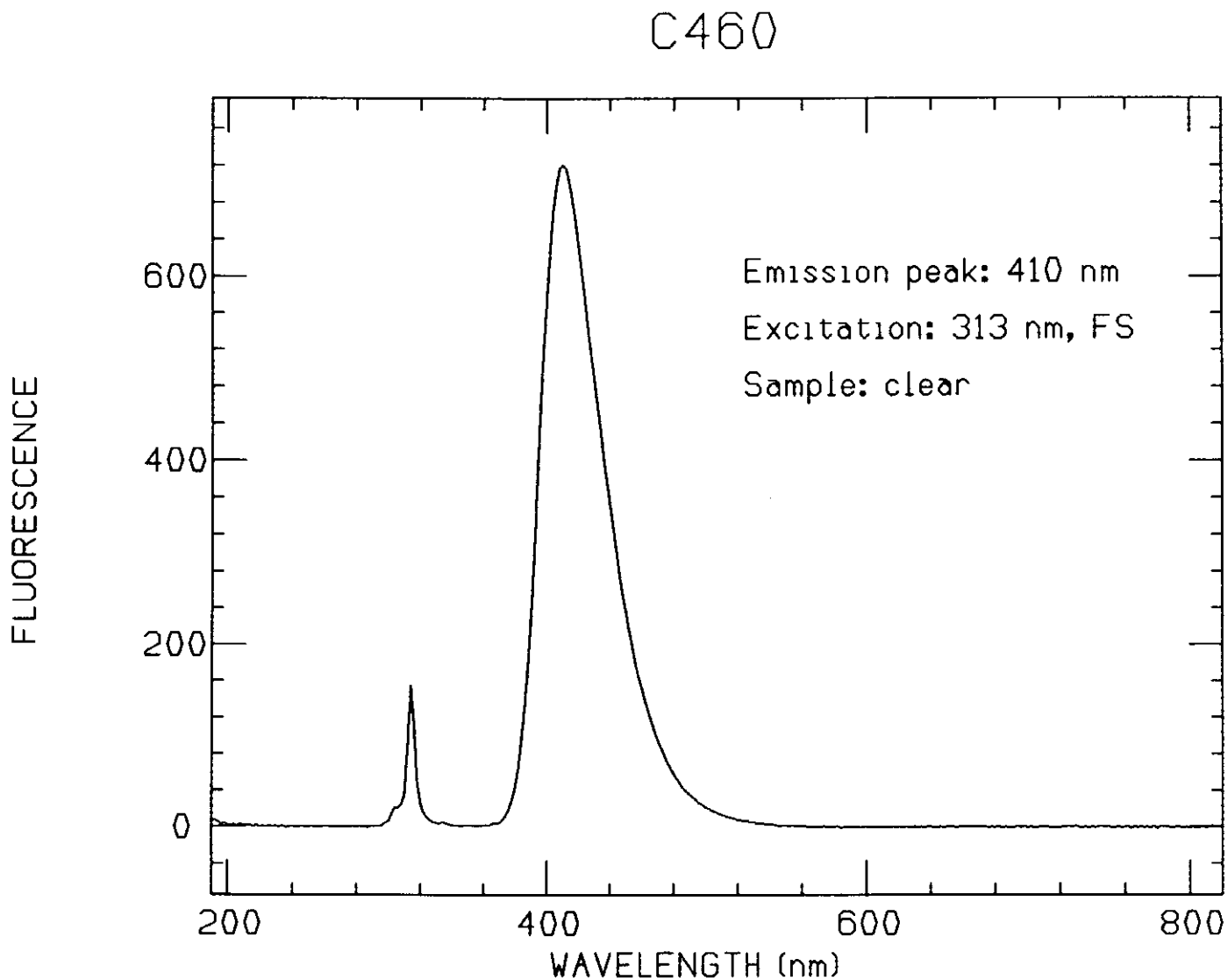

C440
FLUORESCENCE
1250
1000
750
500
250
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 394 nm
Excitation: 360 nm, FS
Sample: clear

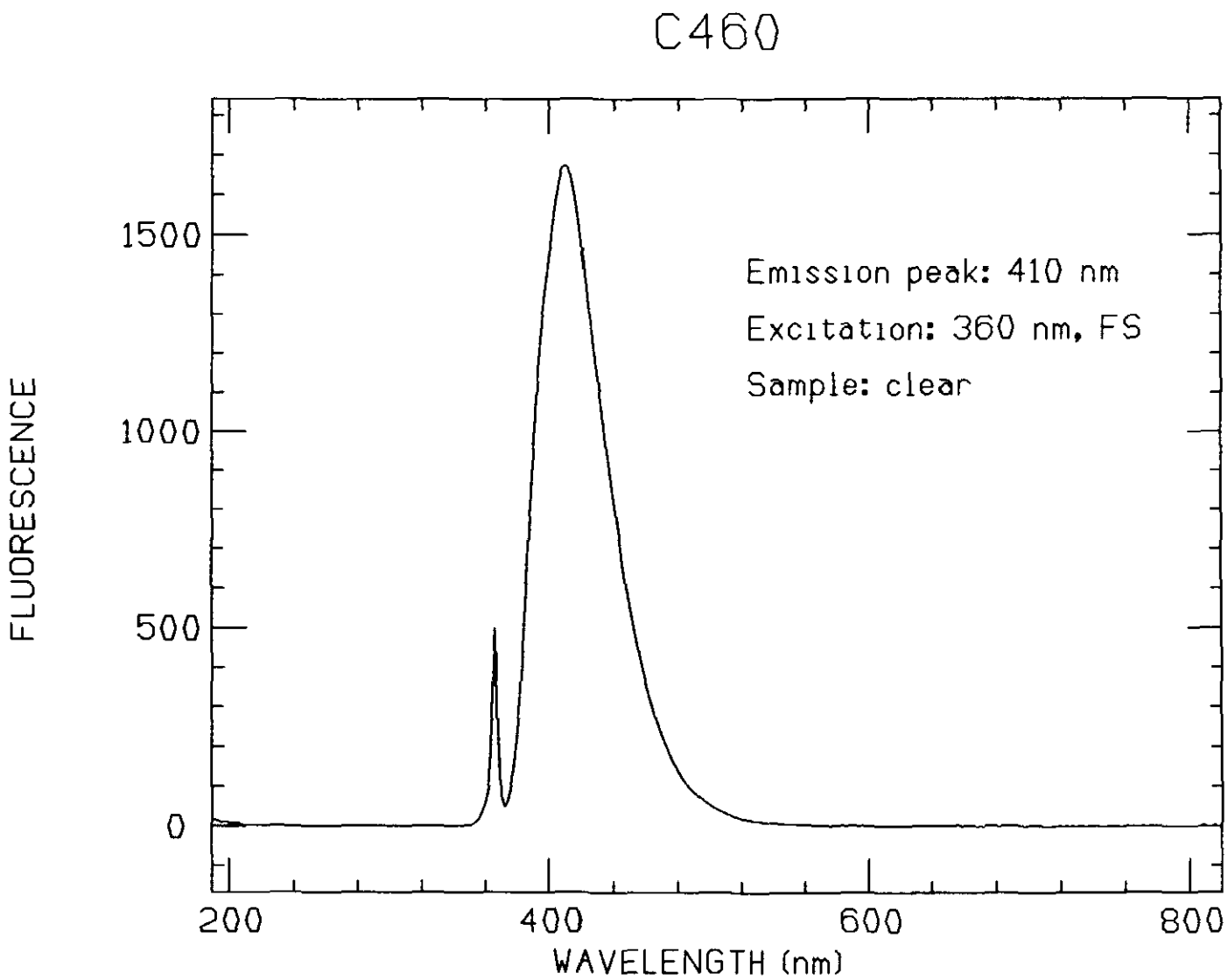

C445
FLUORESCENCE
600
400
200
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 402 nm
Excitation: 313 nm, FS
Sample: clear

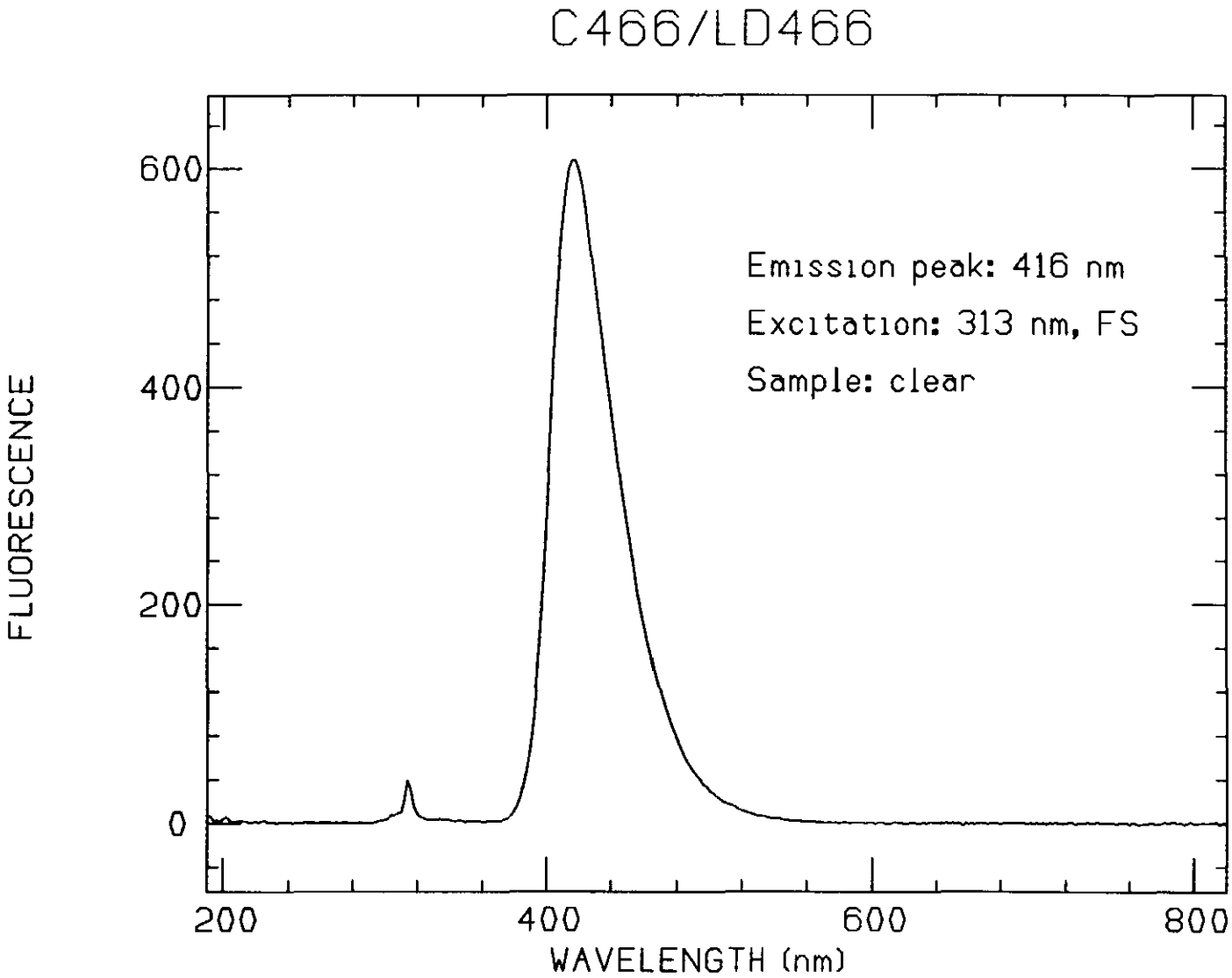

C445
FLUORESCENCE
1500
1000
500
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 402 nm
Excitation: 360 nm, FS
Sample: clear

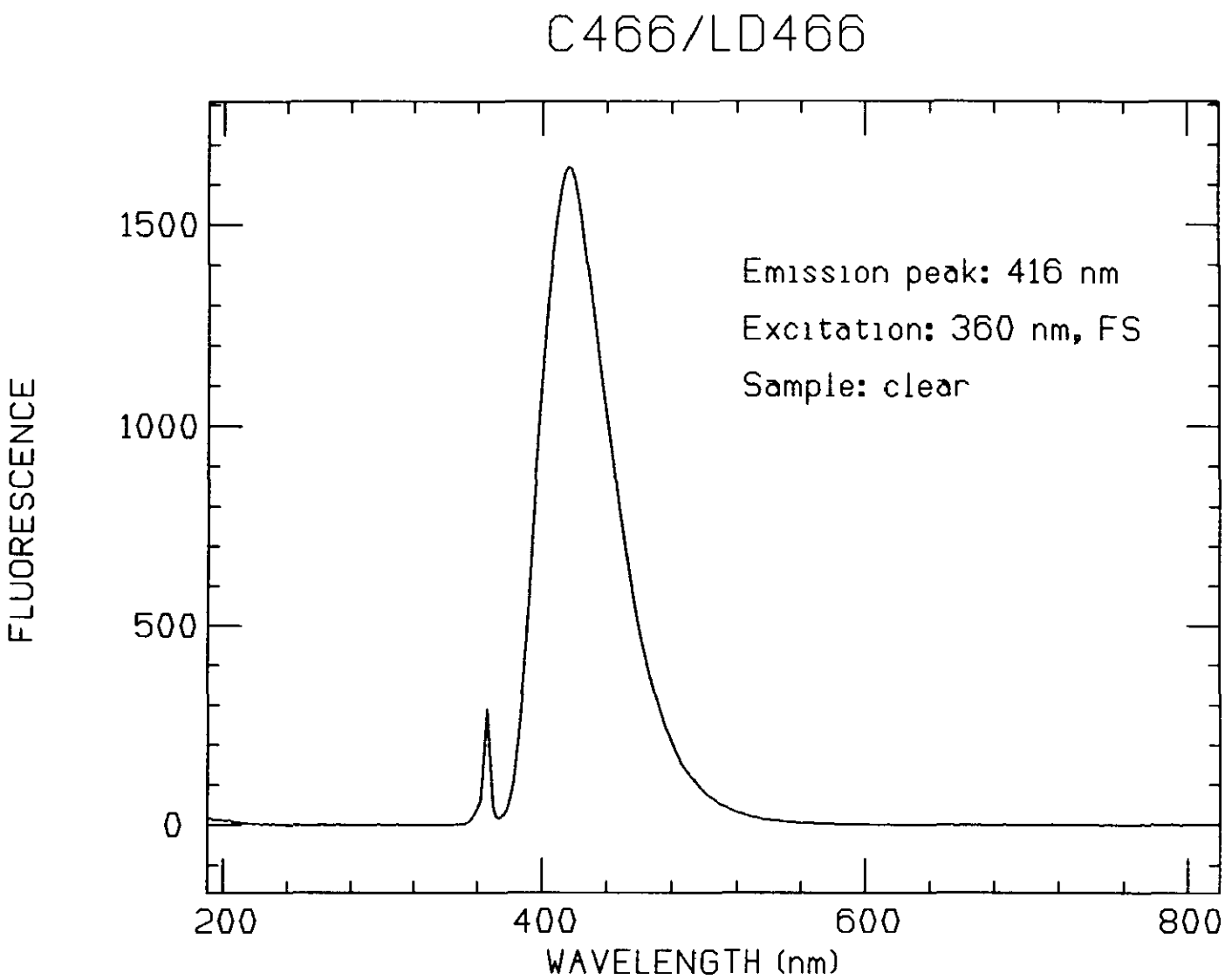

C450
FLUORESCENCE
600
400
200
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 400 nm
Excitation: 313 nm, FS
Sample: clear

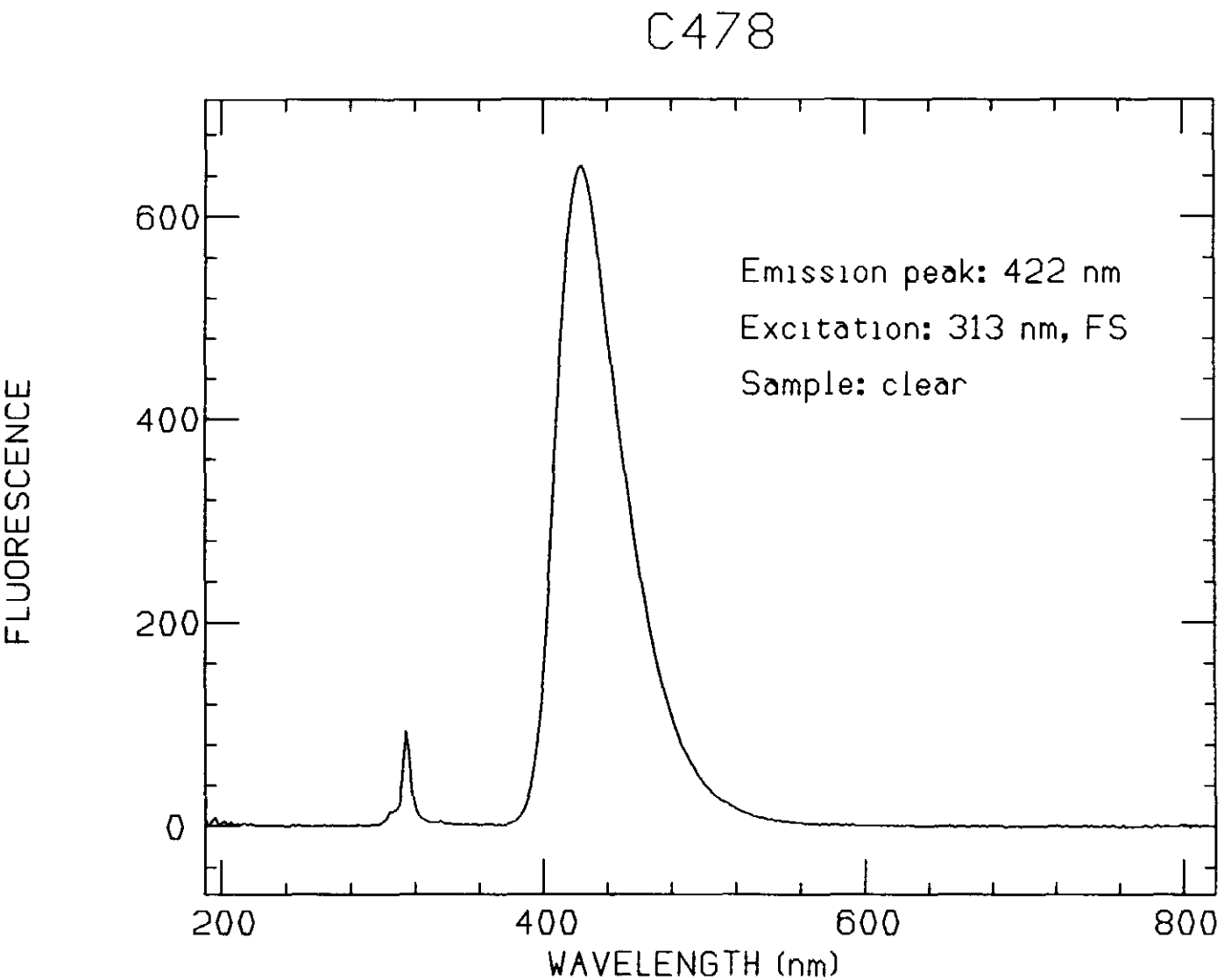

C450
1500
1000
500
0
FLUORESCENCE
200
400
600
800
WAVELENGTH (nm)
Emission peak: 402 nm
Excitation: 360 nm, FS
Sample: clear

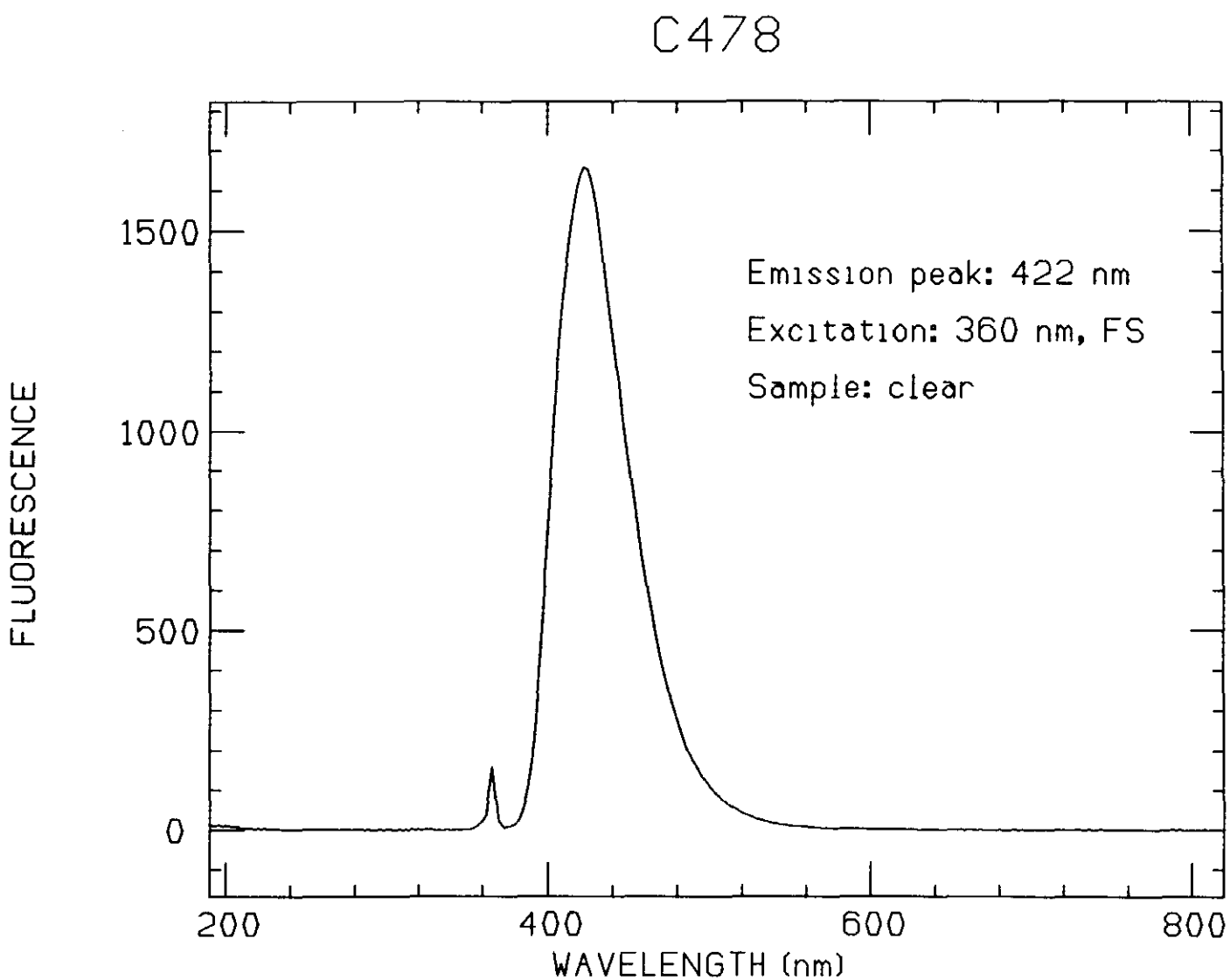

C460
FLUORESCENCE
600
400
200
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 410 nm
Excitation: 313 nm, FS
Sample: clear

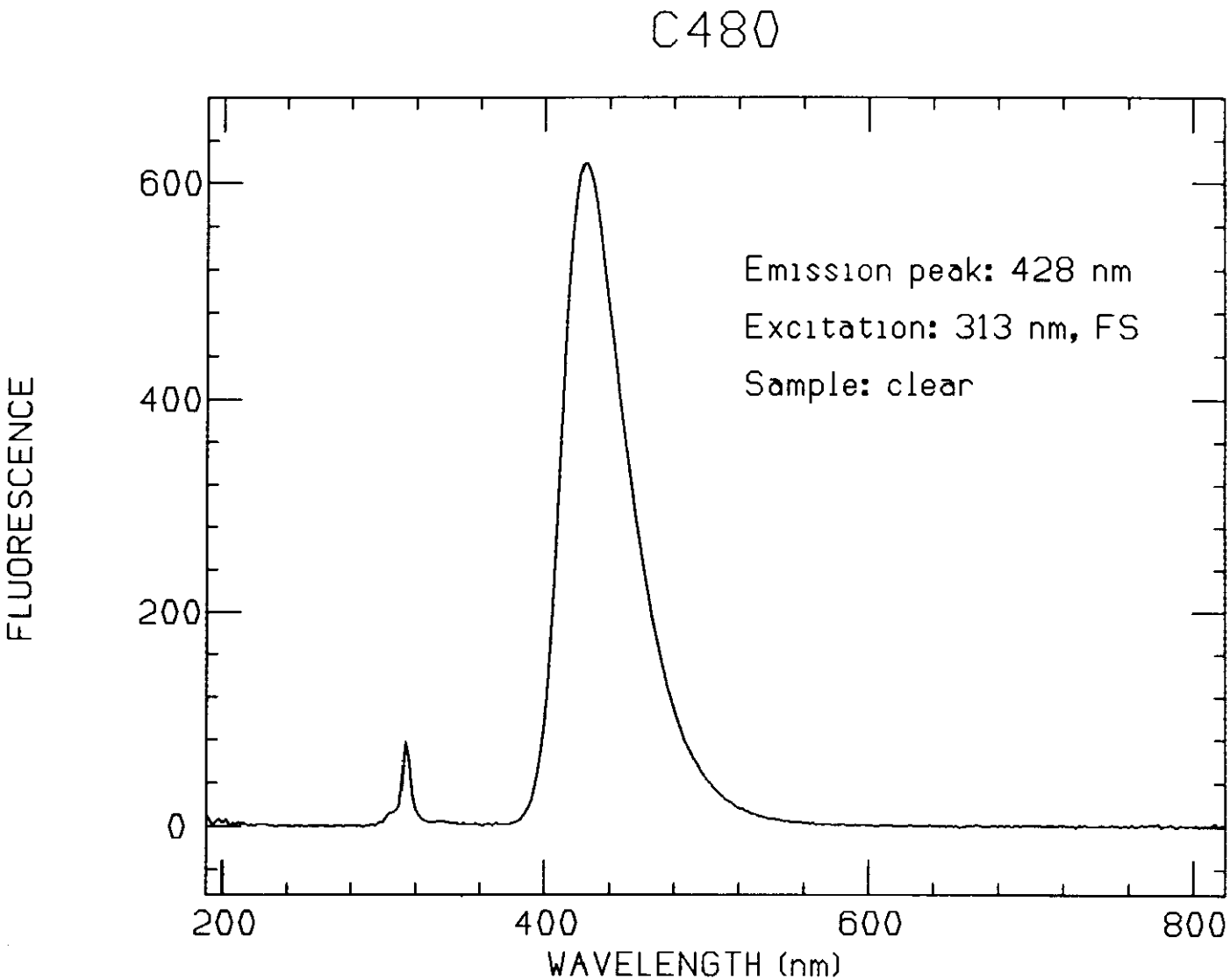

C460
FLUORESCENCE
1500
1000
500
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 410 nm
Excitation: 360 nm, FS
Sample: clear

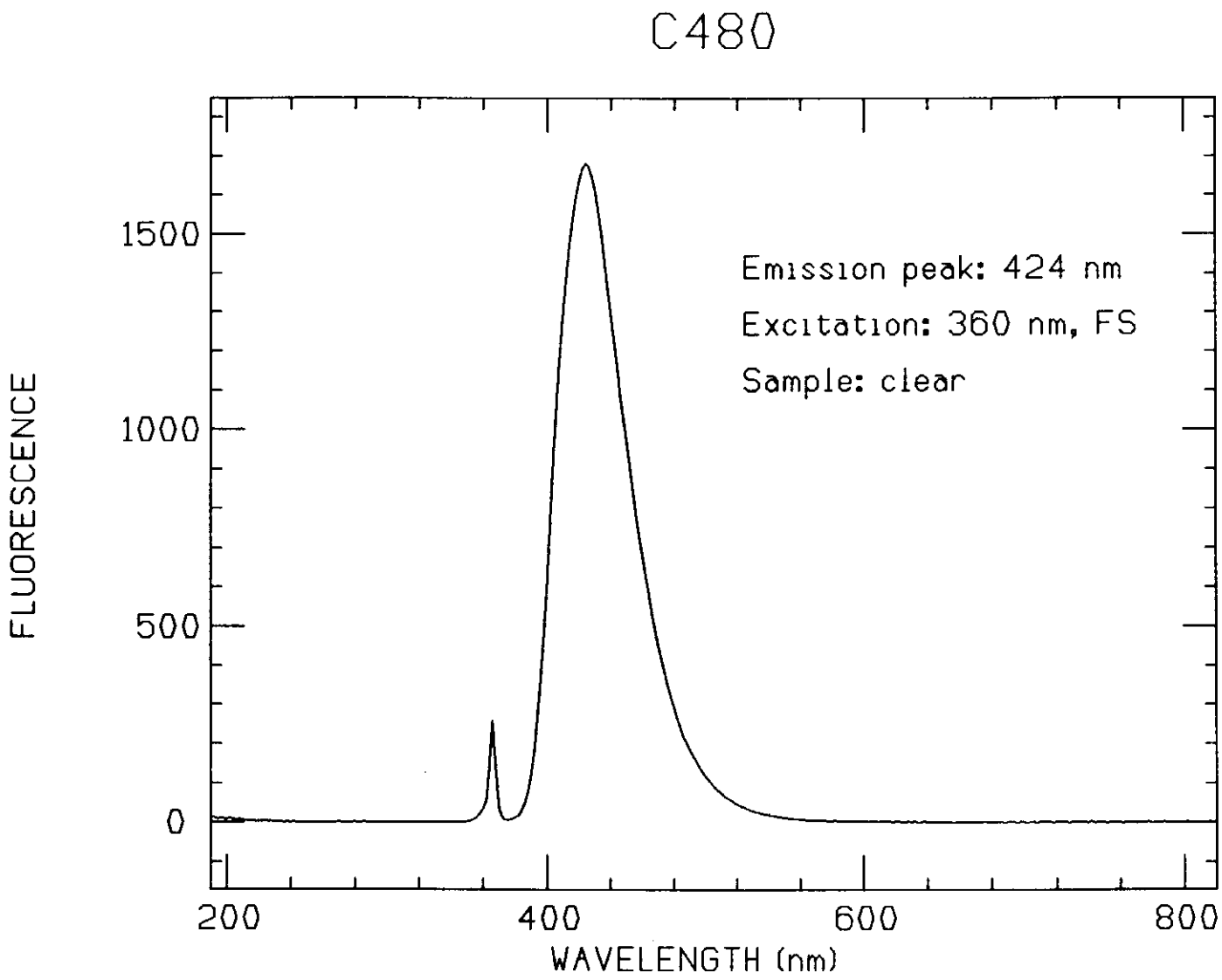

C466/LD466
FLUORESCENCE
600
400
200
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 416 nm
Excitation: 313 nm, FS
Sample: clear

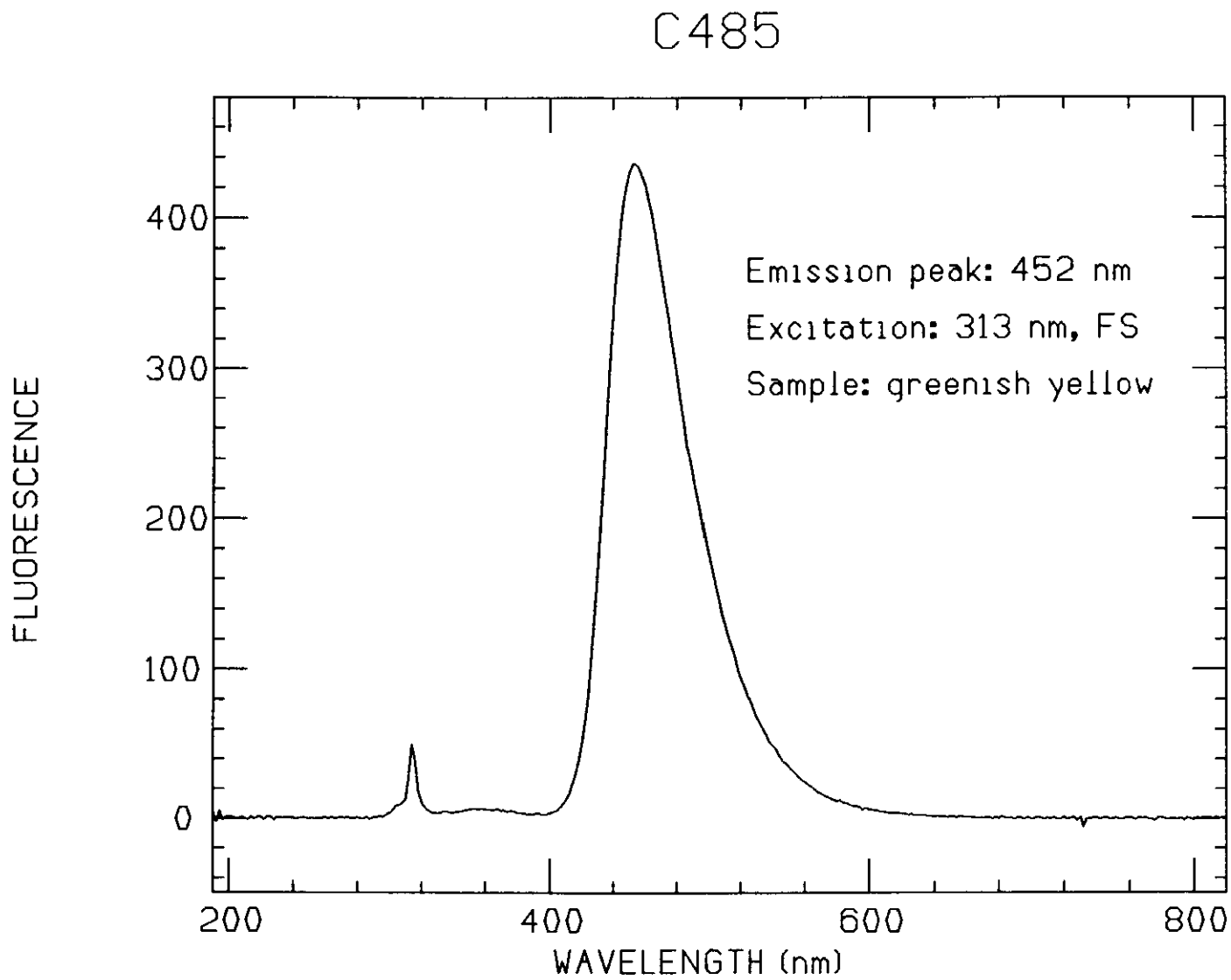

C466/LD466
FLUORESCENCE
1500
1000
500
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 416 nm
Excitation: 360 nm, FS
Sample: clear

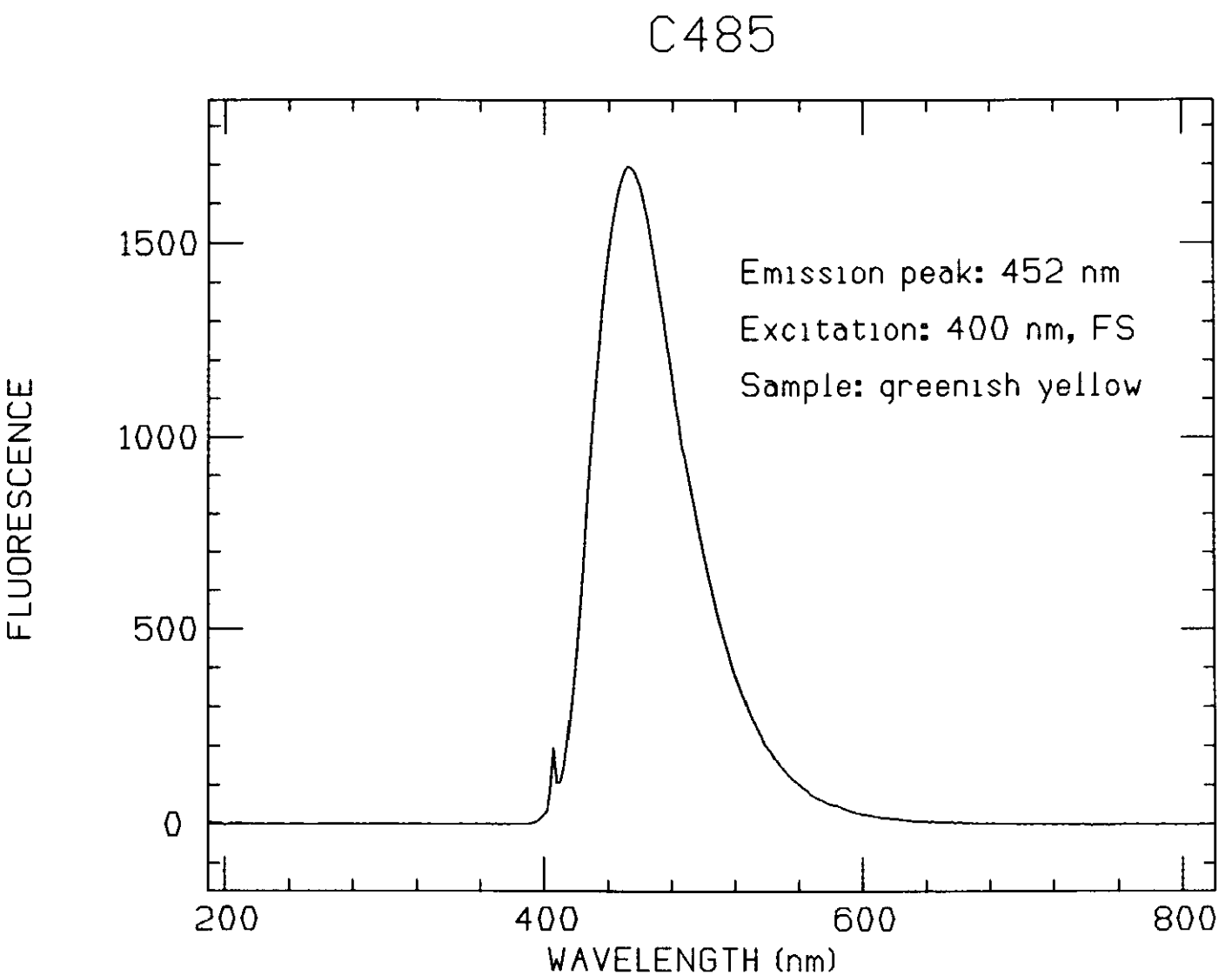

C478
FLUORESCENCE
600
400
200
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 422 nm
Excitation: 313 nm, FS
Sample: clear

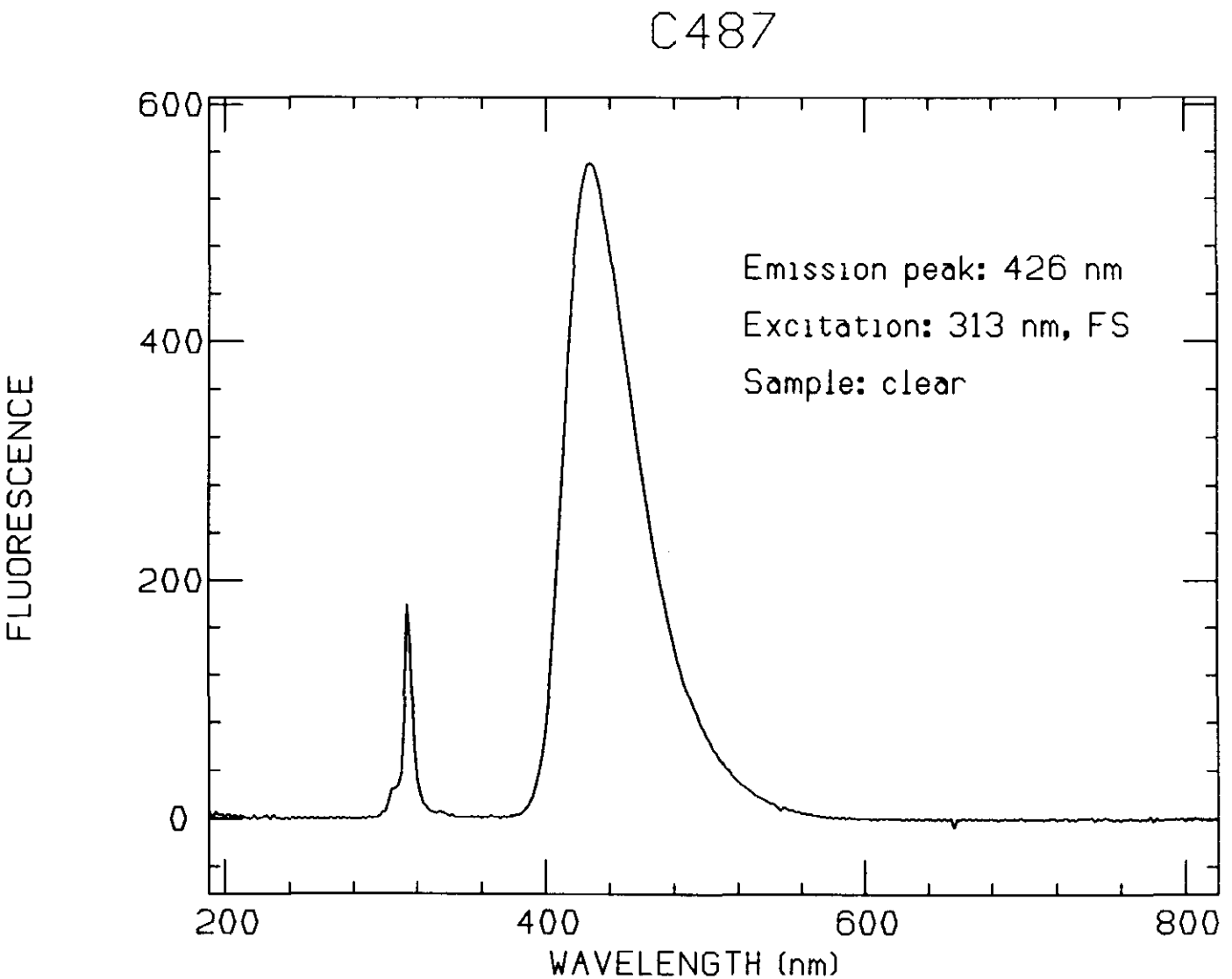

C478
FLUORESCENCE
1500
1000
500
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 422 nm
Excitation: 360 nm, FS
Sample: clear

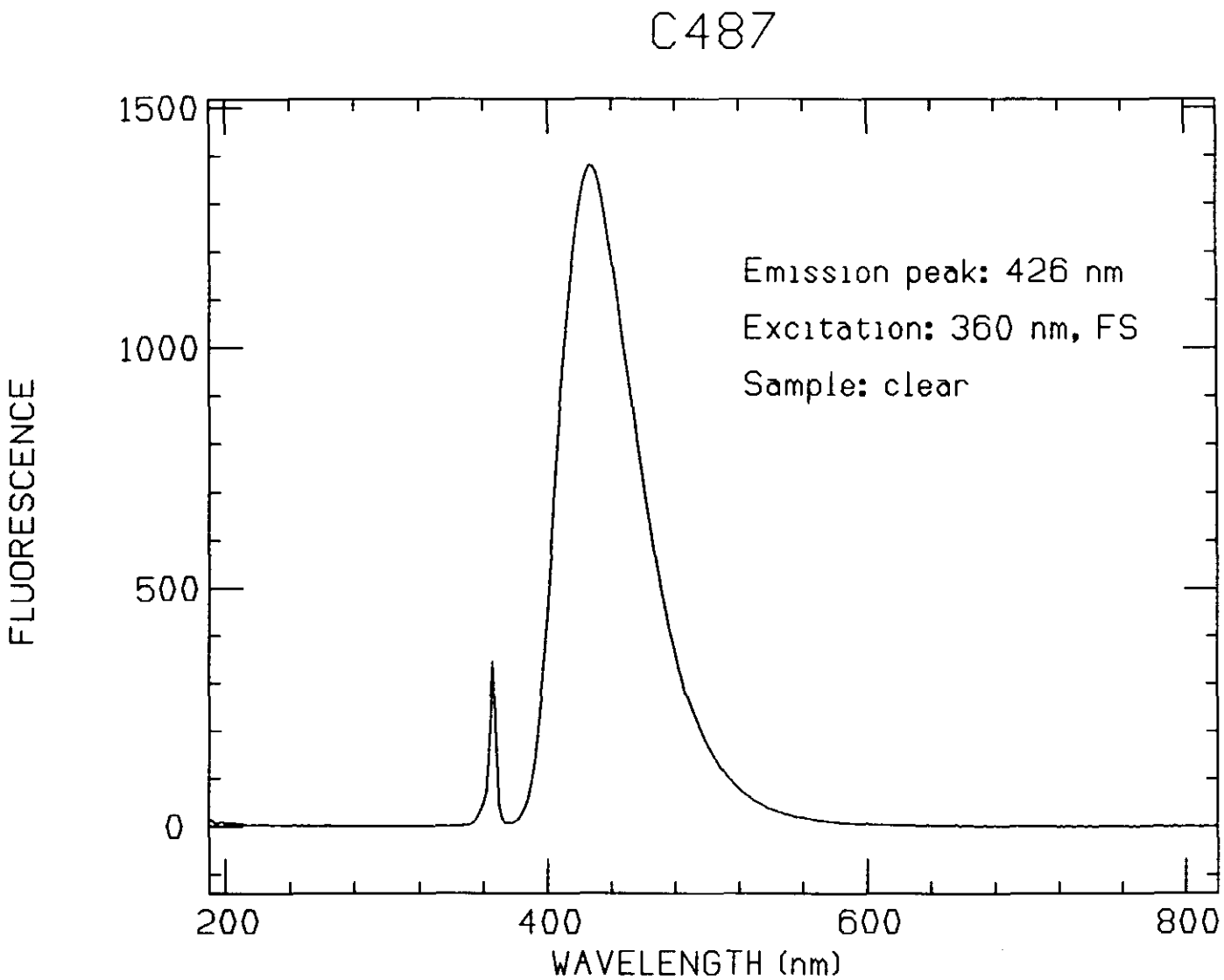

C480
FLUORESCENCE
600
400
200
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 428 nm
Excitation: 313 nm, FS
Sample: clear

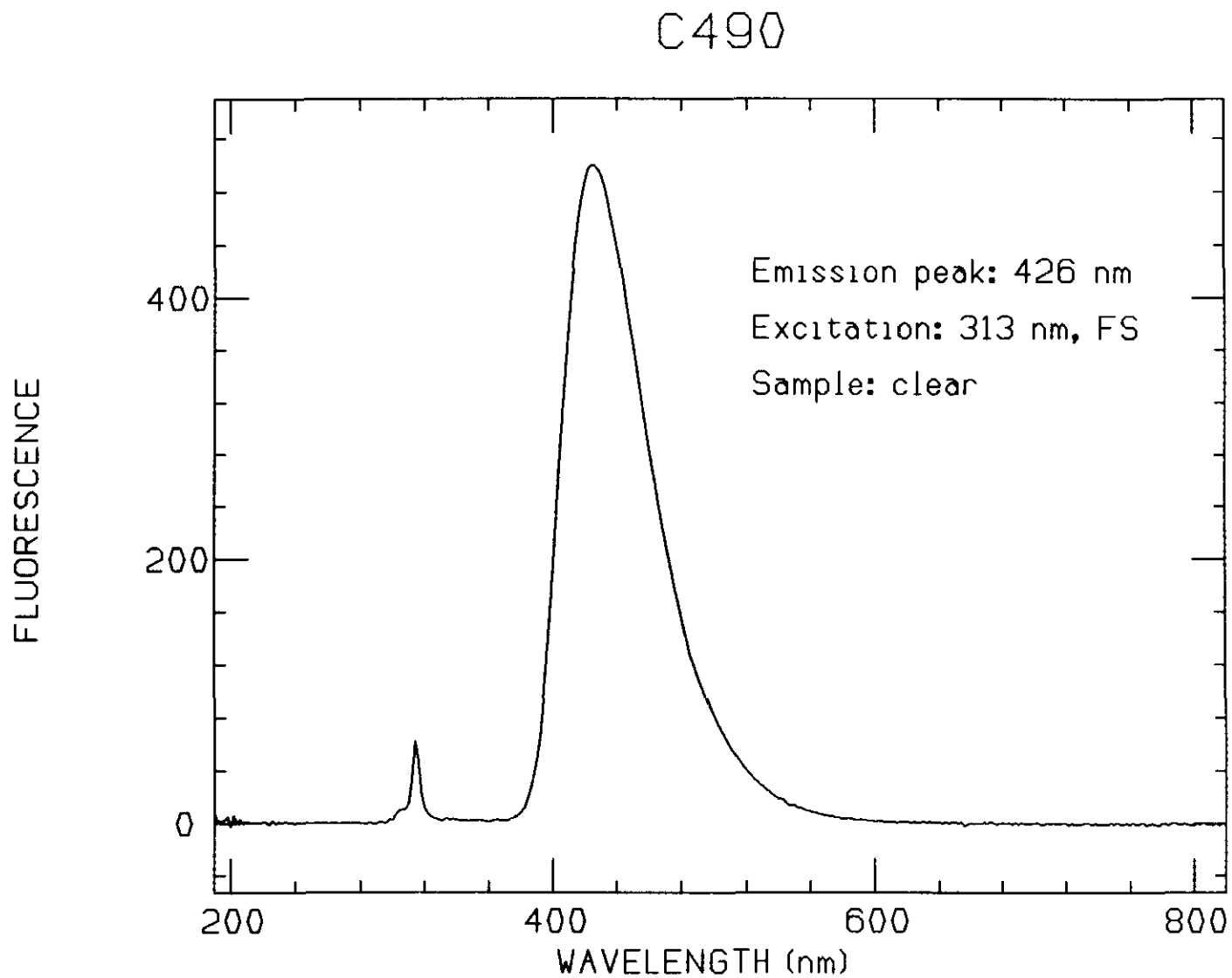

C480
FLUORESCENCE
1500
1000
500
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 424 nm
Excitation: 360 nm, FS
Sample: clear

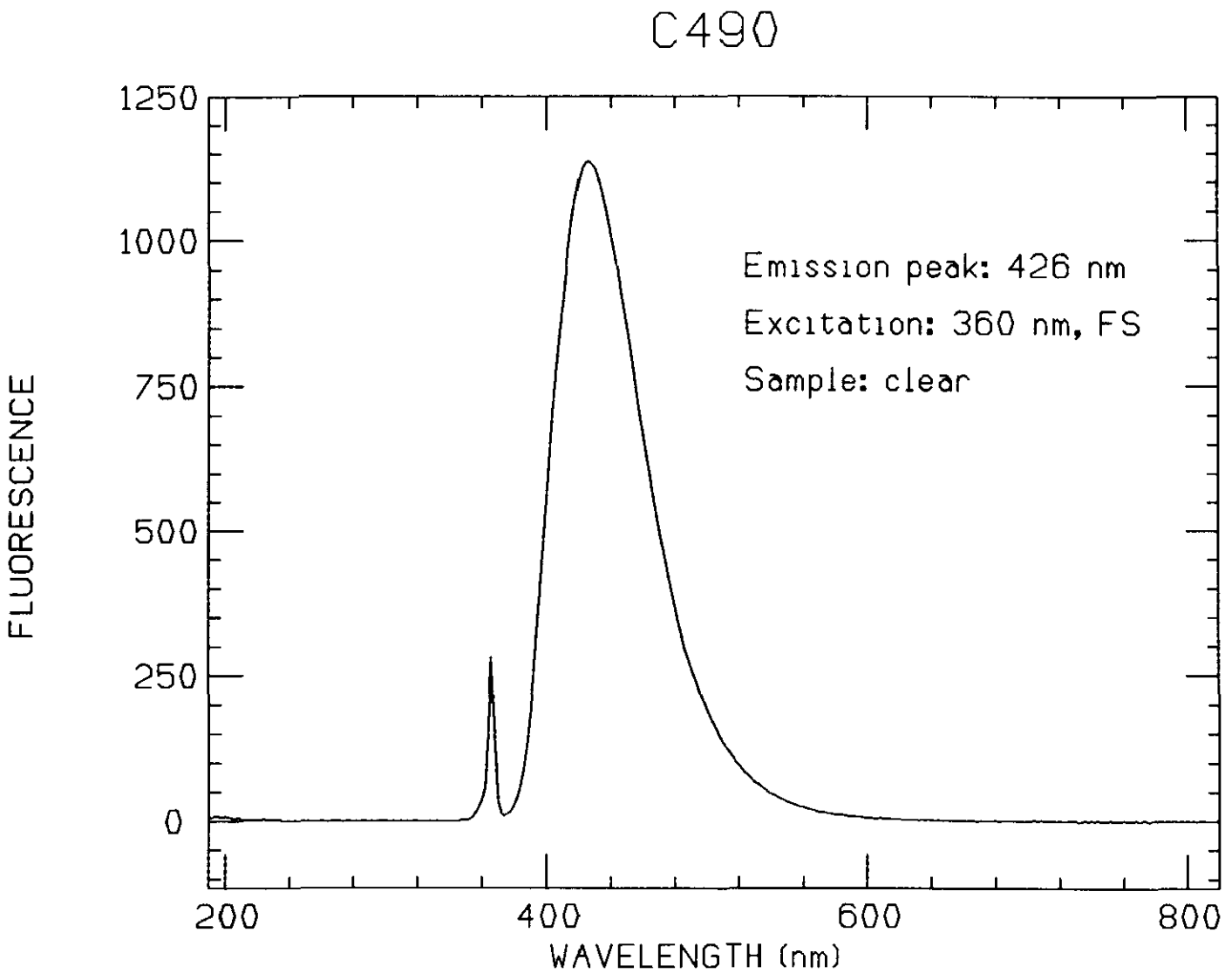

C485
FLUORESCENCE
400
300
200
100
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 452 nm
Excitation: 313 nm, FS
Sample: greenish yellow

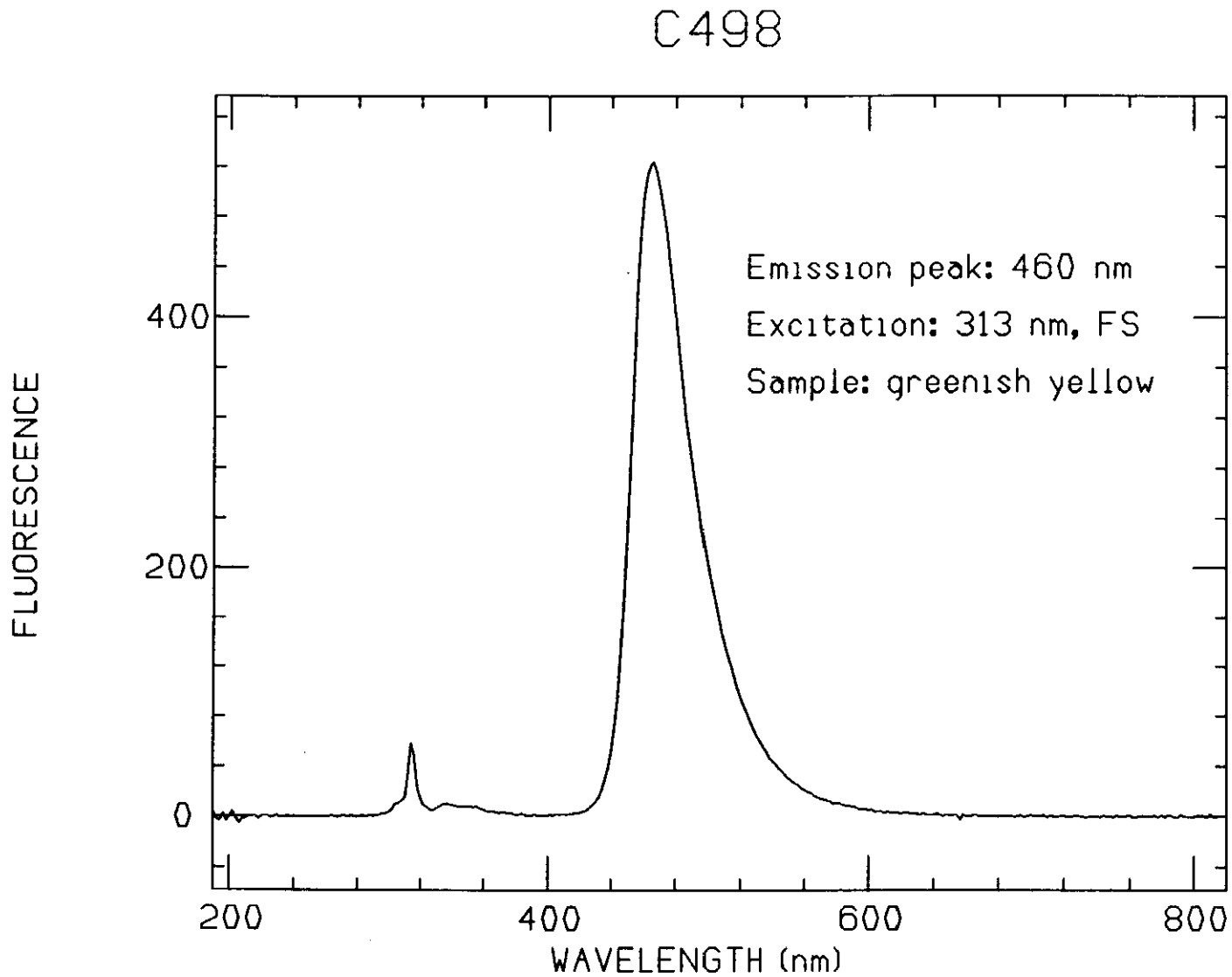

C485
FLUORESCENCE
1500
1000
500
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 452 nm
Excitation: 400 nm, FS
Sample: greenish yellow

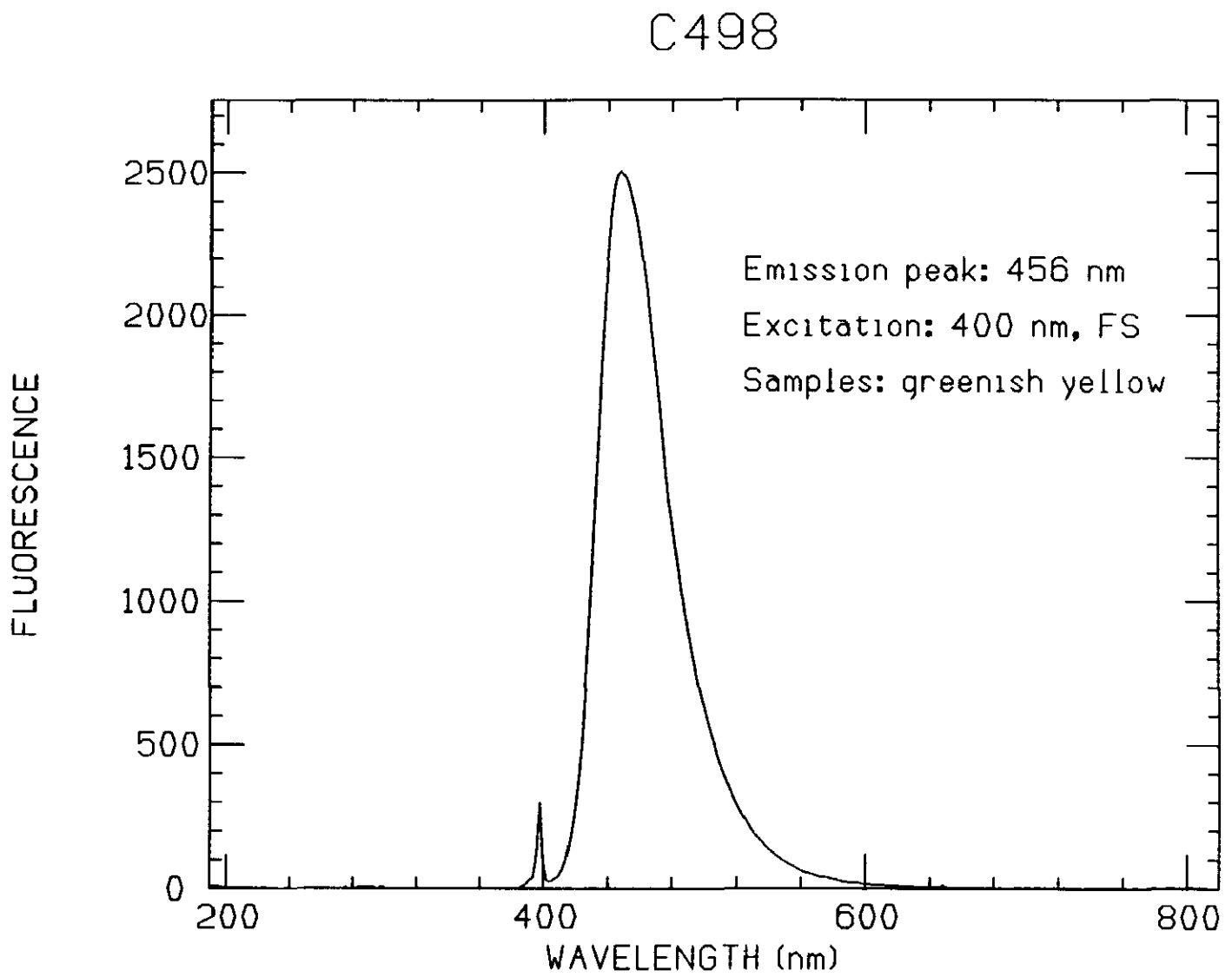

C487
600
400
200
0
FLUORESCENCE
Emission peak: 426 nm
Excitation: 313 nm, FS
Sample: clear
200
400
600
800
WAVELENGTH (nm)

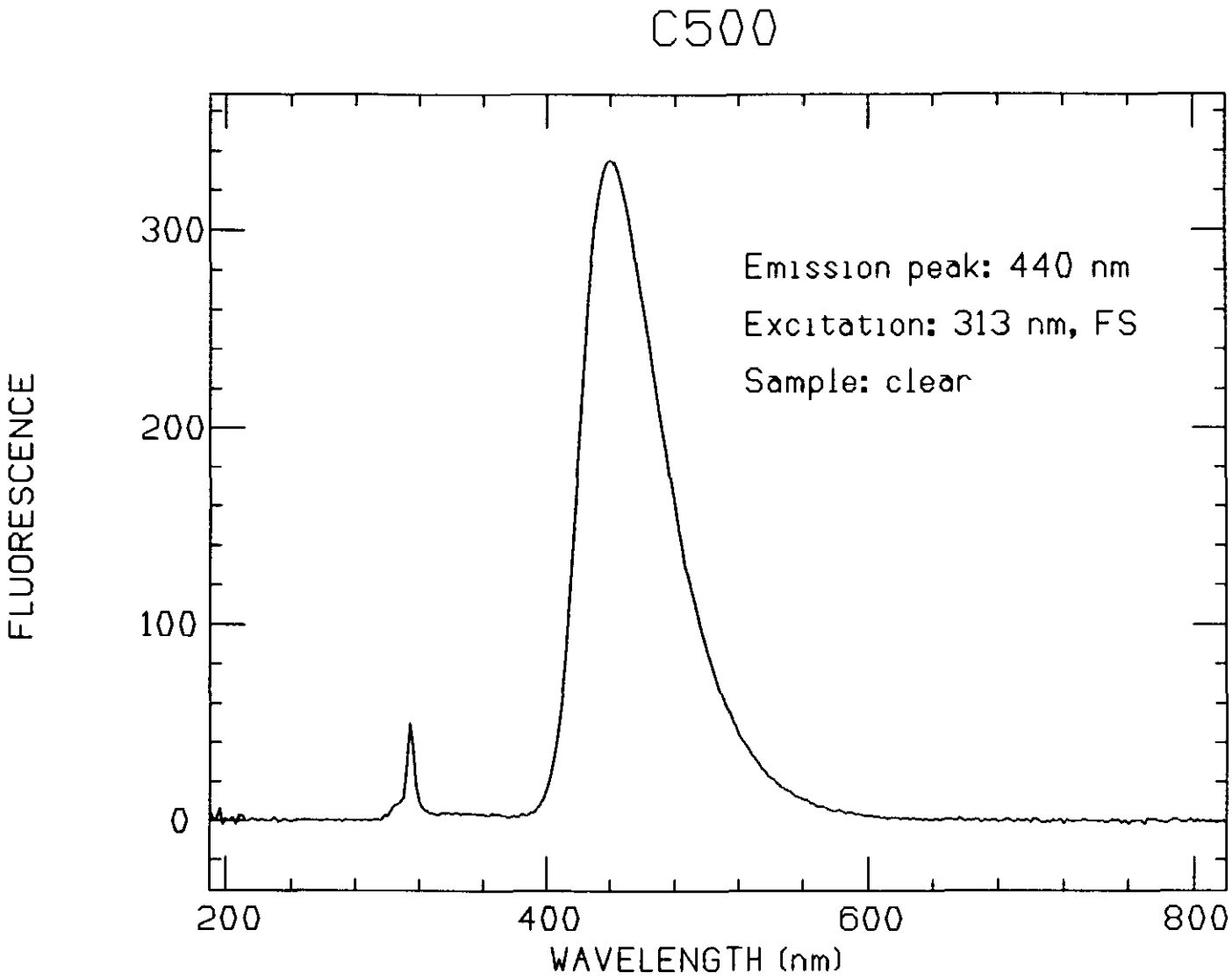

C487
1500
1000
500
0
FLUORESCENCE
Emission peak: 426 nm
Excitation: 360 nm, FS
Sample: clear
200
400
600
800
WAVELENGTH (nm)

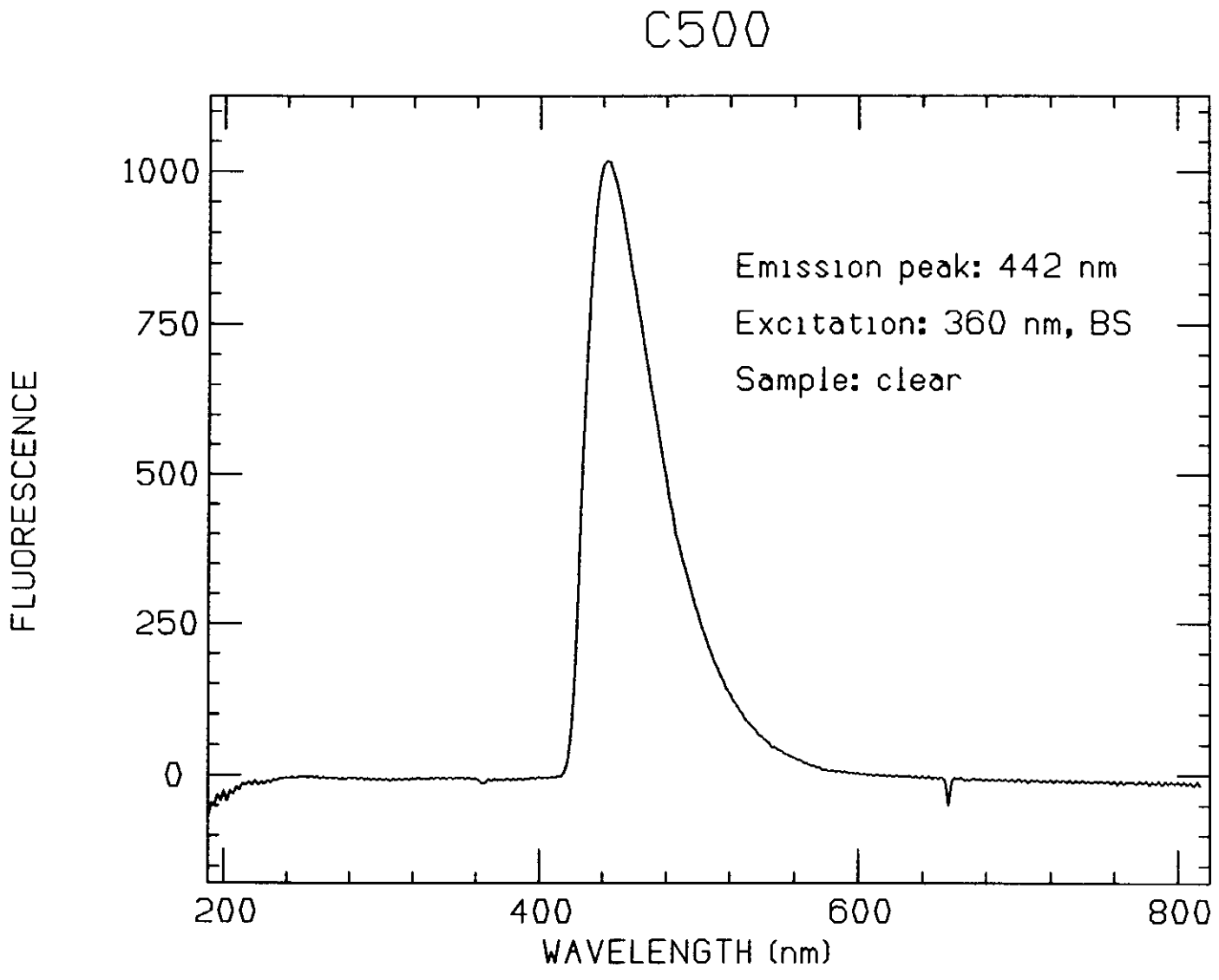

C490
Emission peak: 426 nm
Excitation: 313 nm, FS
Sample: clear
FLUORESCENCE
0
200
400
200
400
600
800
WAVELENGTH (nm)

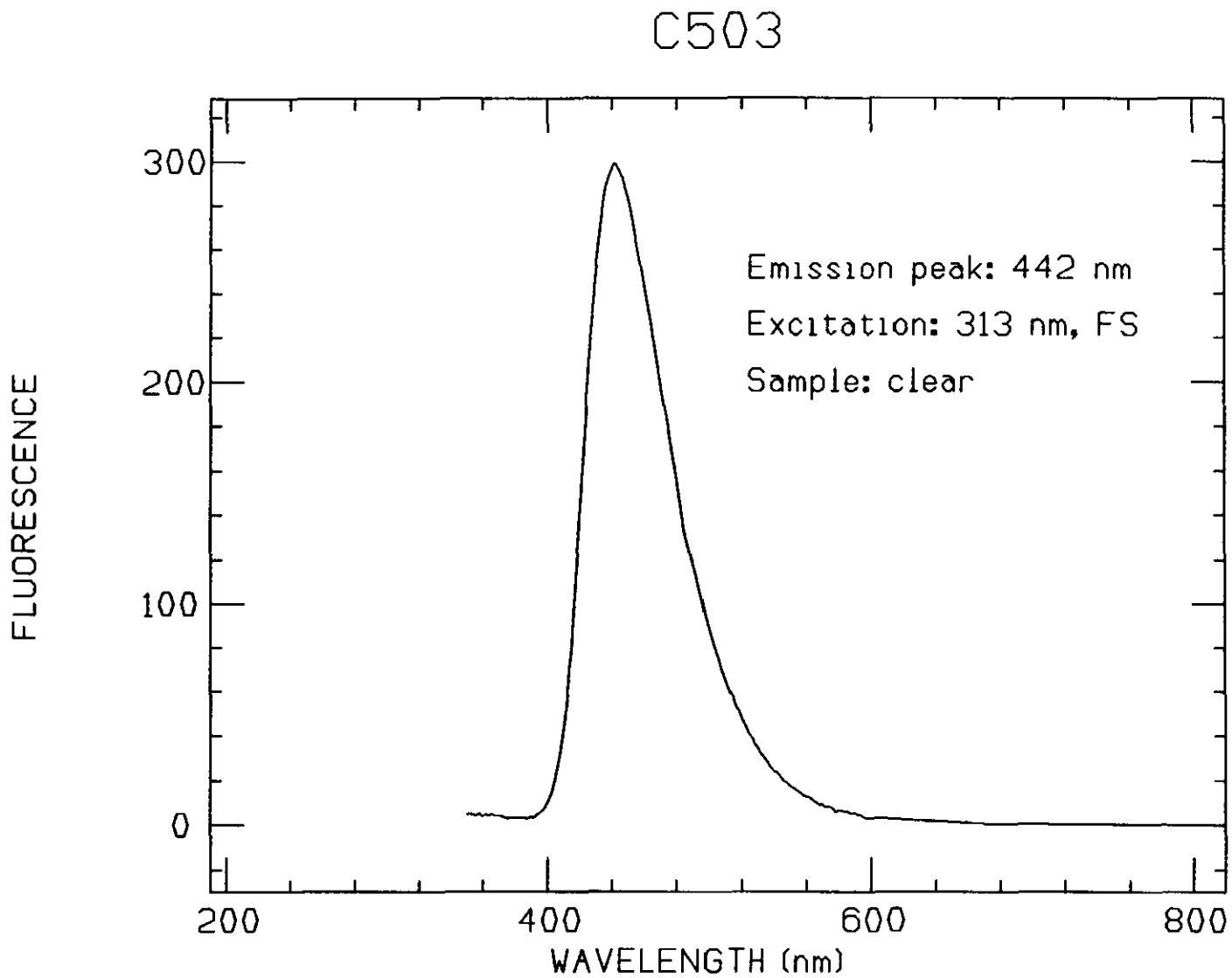

C490
1250
1000
750
500
250
0
FLUORESCENCE
Emission peak: 426 nm
Excitation: 360 nm, FS
Sample: clear
200
400
600
800
WAVELENGTH (nm)

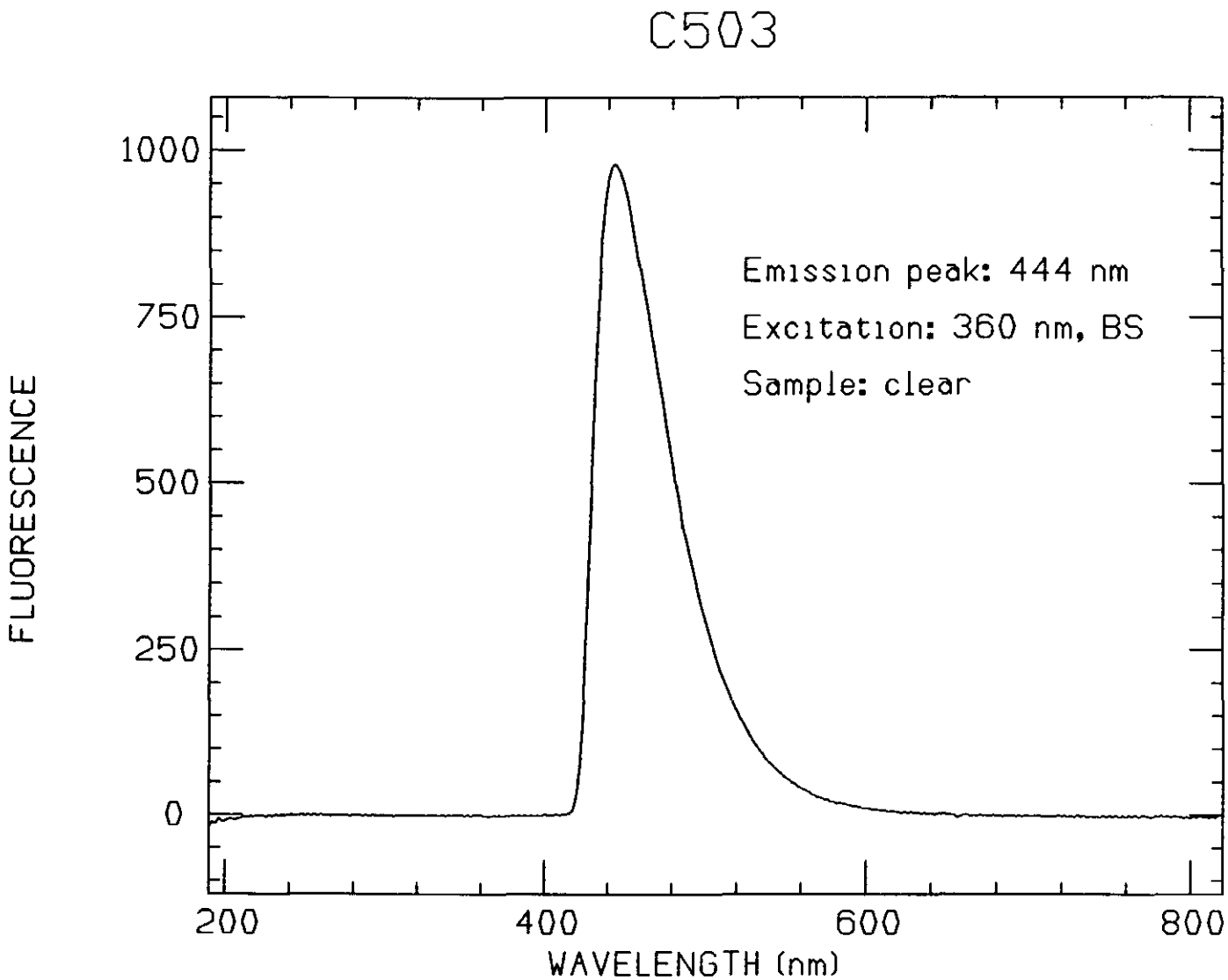

C498
Emission peak: 460 nm
Excitation: 313 nm, FS
Sample: greenish yellow
FLUORESCENCE
400
200
0
200
400
600
800
WAVELENGTH (nm)

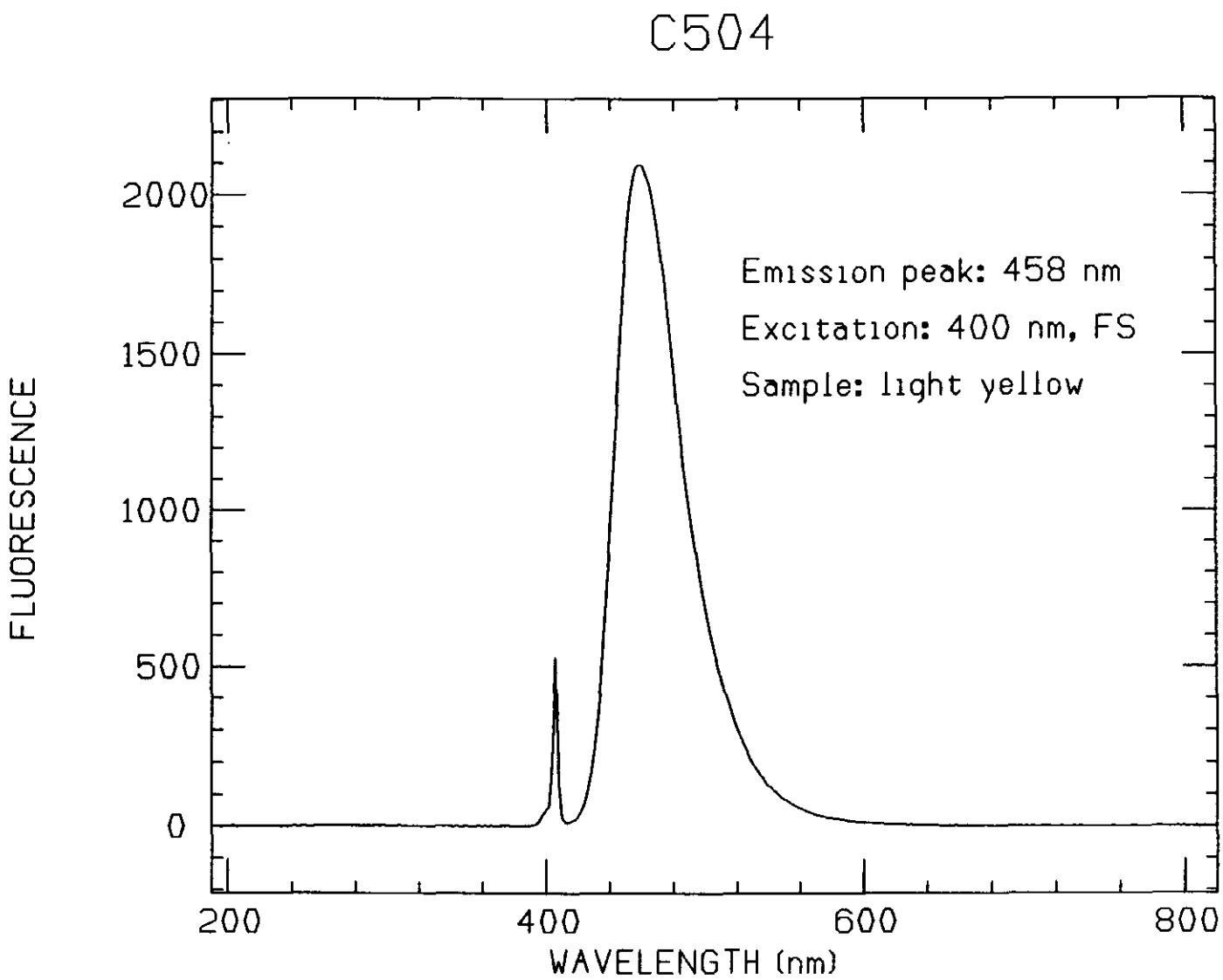

C498
FLUORESCENCE
2500
2000
1500
1000
500
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 456 nm
Excitation: 400 nm, FS
Samples: greenish yellow

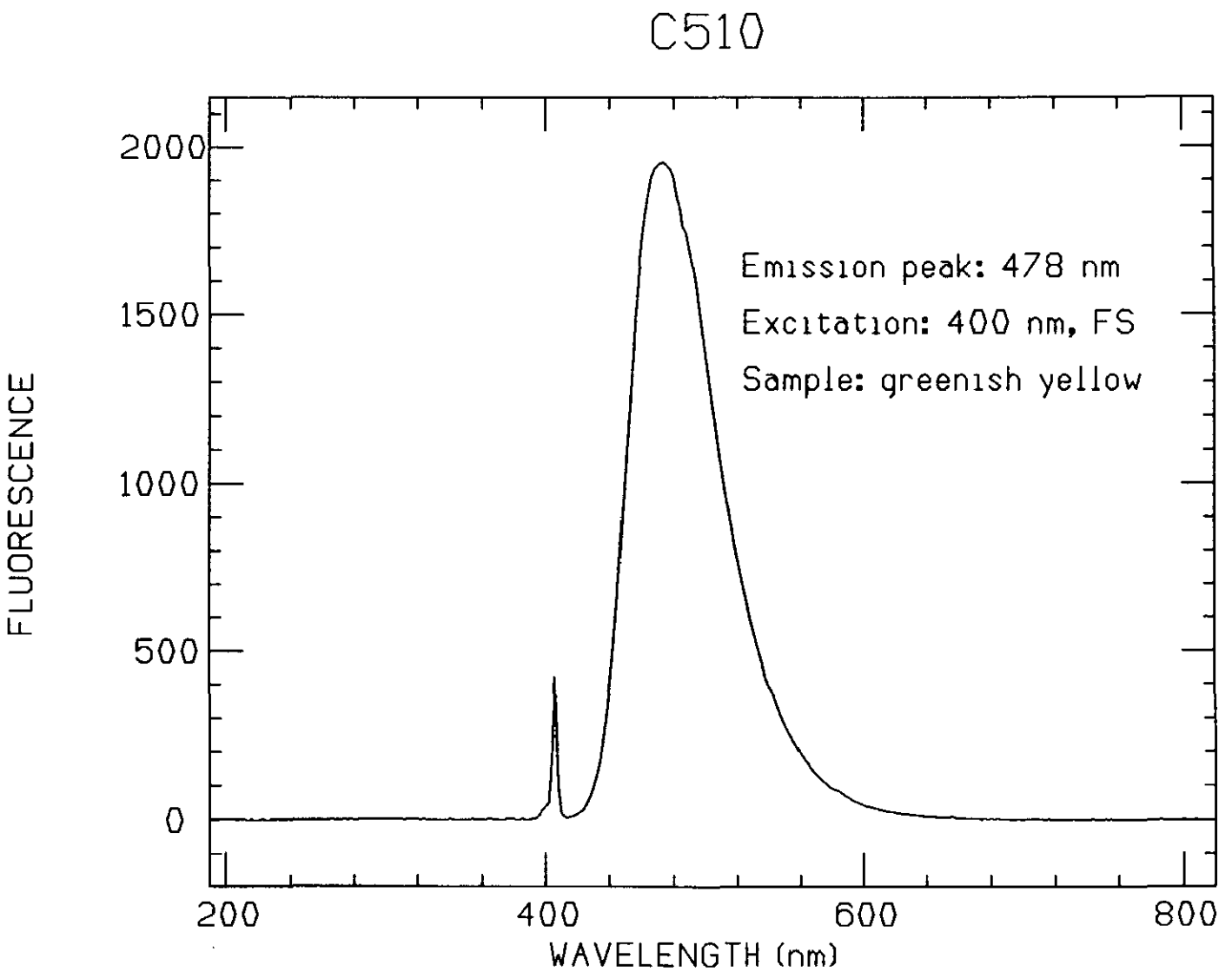

C500
FLUORESCENCE
300
200
100
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 440 nm
Excitation: 313 nm, FS
Sample: clear

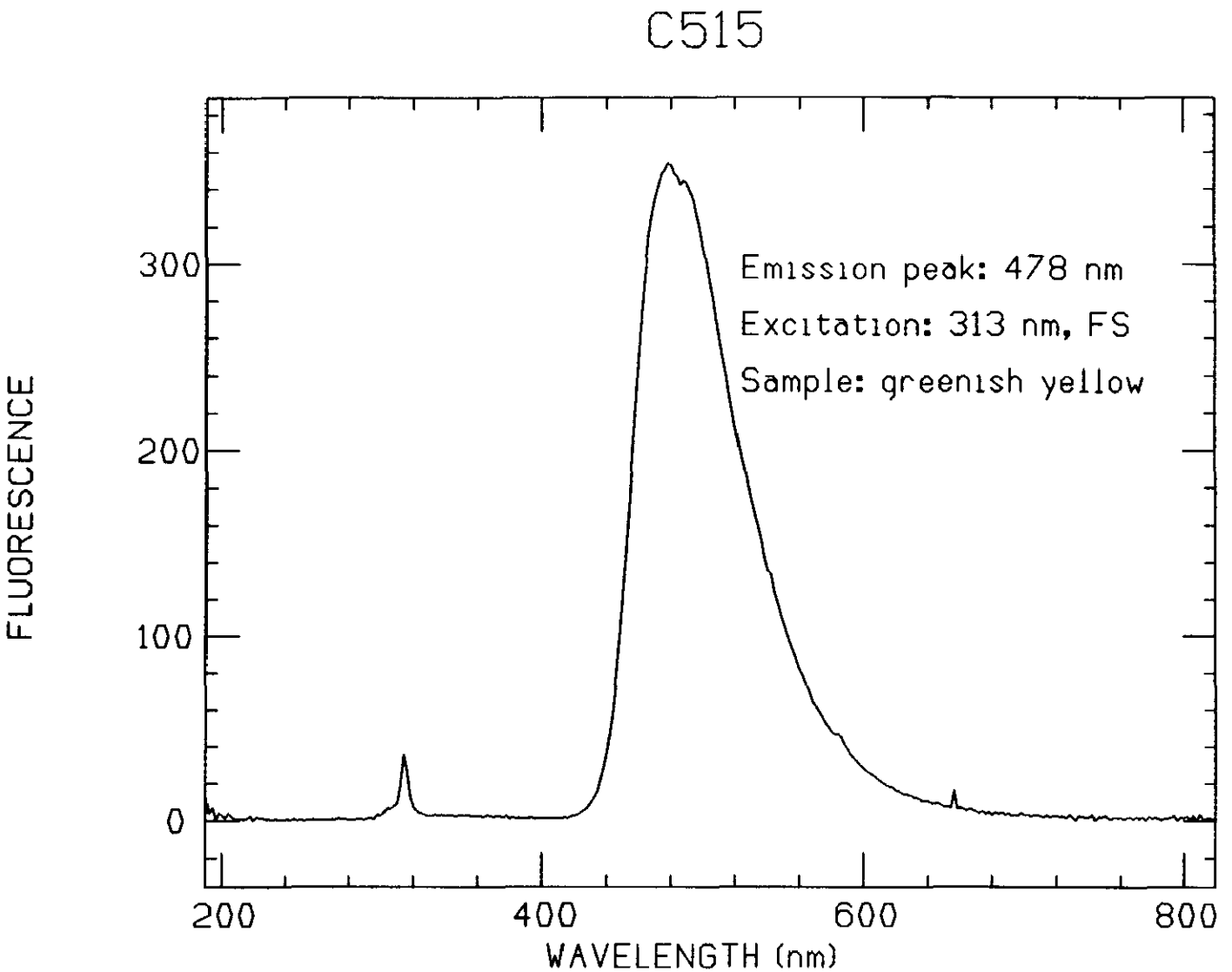

C500
FLUORESCENCE
1000
750
500
250
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 442 nm
Excitation: 360 nm, BS
Sample: clear

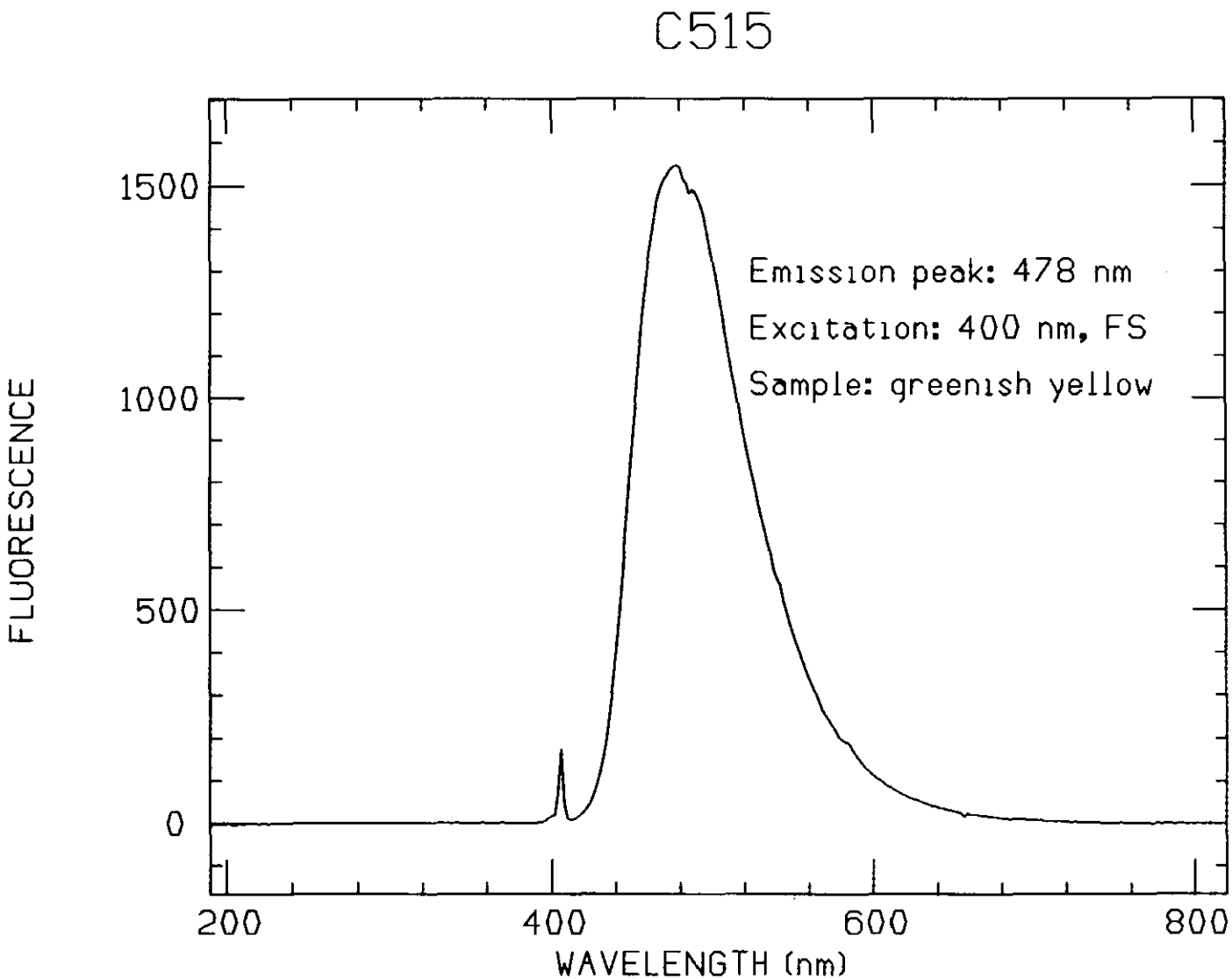

C503
FLUORESCENCE
300
200
100
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 442 nm
Excitation: 313 nm, FS
Sample: clear

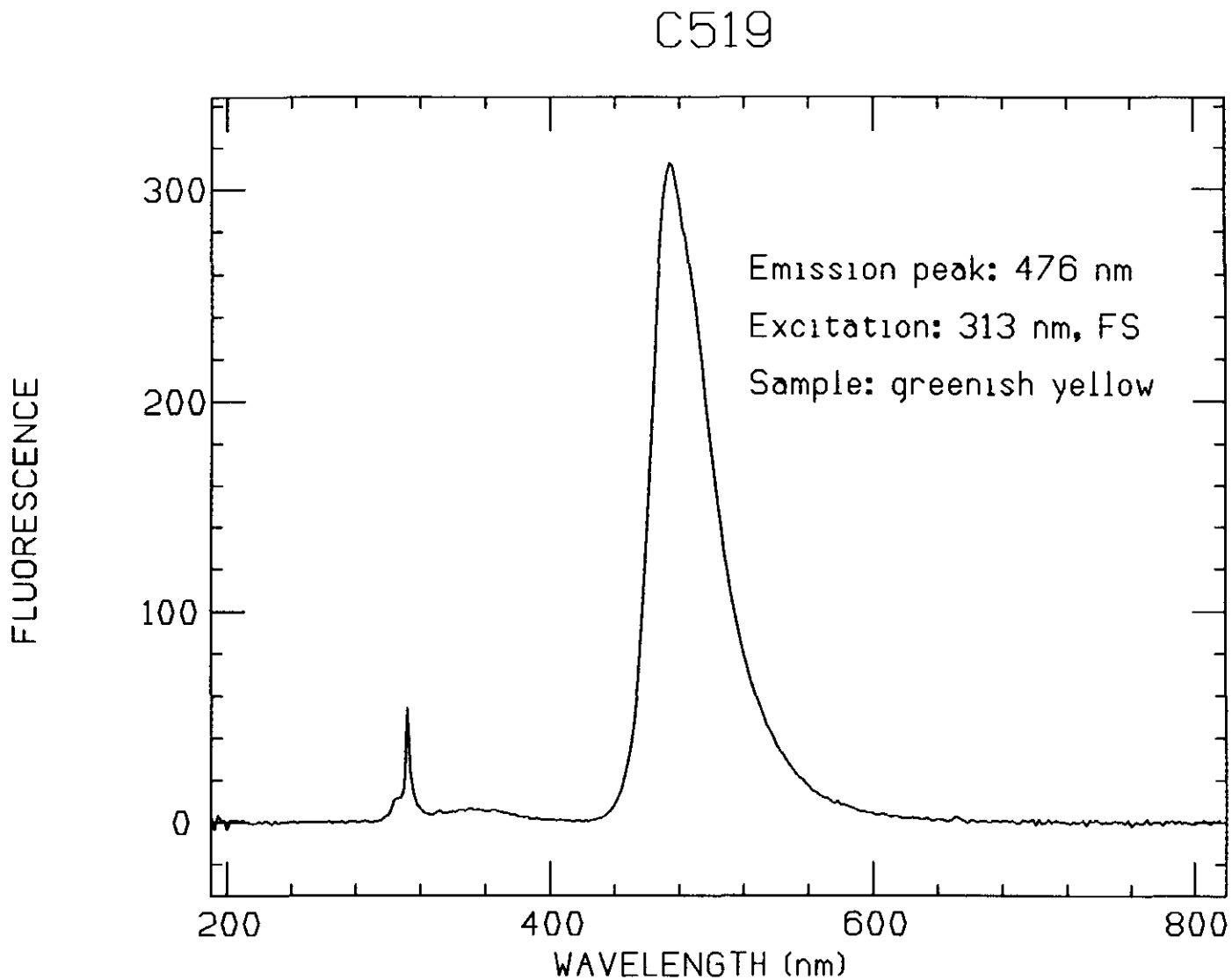

C503
1000
750
500
250
0
FLUORESCENCE
200
400
600
800
WAVELENGTH (nm)
Emission peak: 444 nm
Excitation: 360 nm, BS
Sample: clear

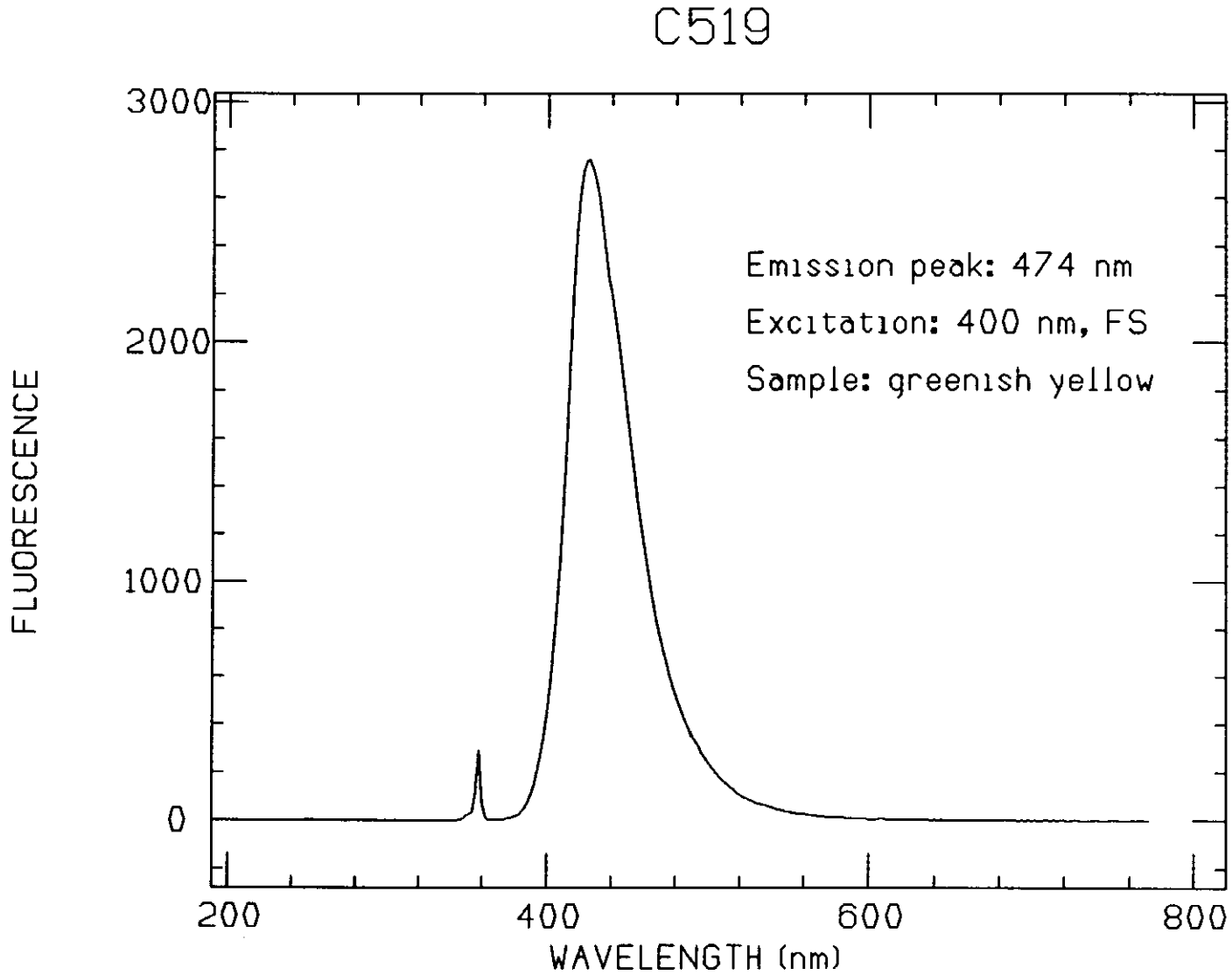

C504
FLUORESCENCE
2000
1500
1000
500
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 458 nm
Excitation: 400 nm, FS
Sample: light yellow

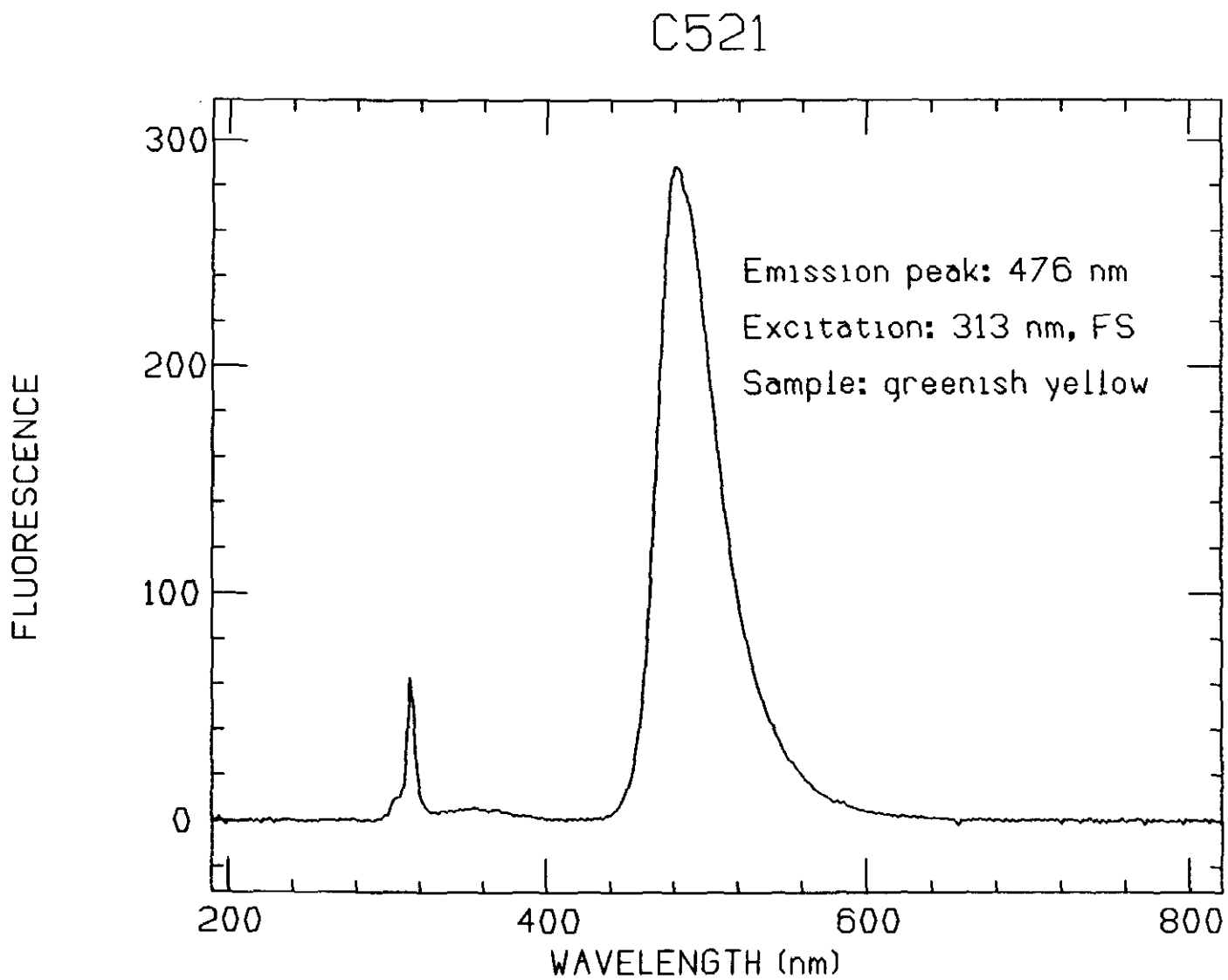

C510
FLUORESCENCE
2000
1500
1000
500
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 478 nm
Excitation: 400 nm, FS
Sample: greenish yellow

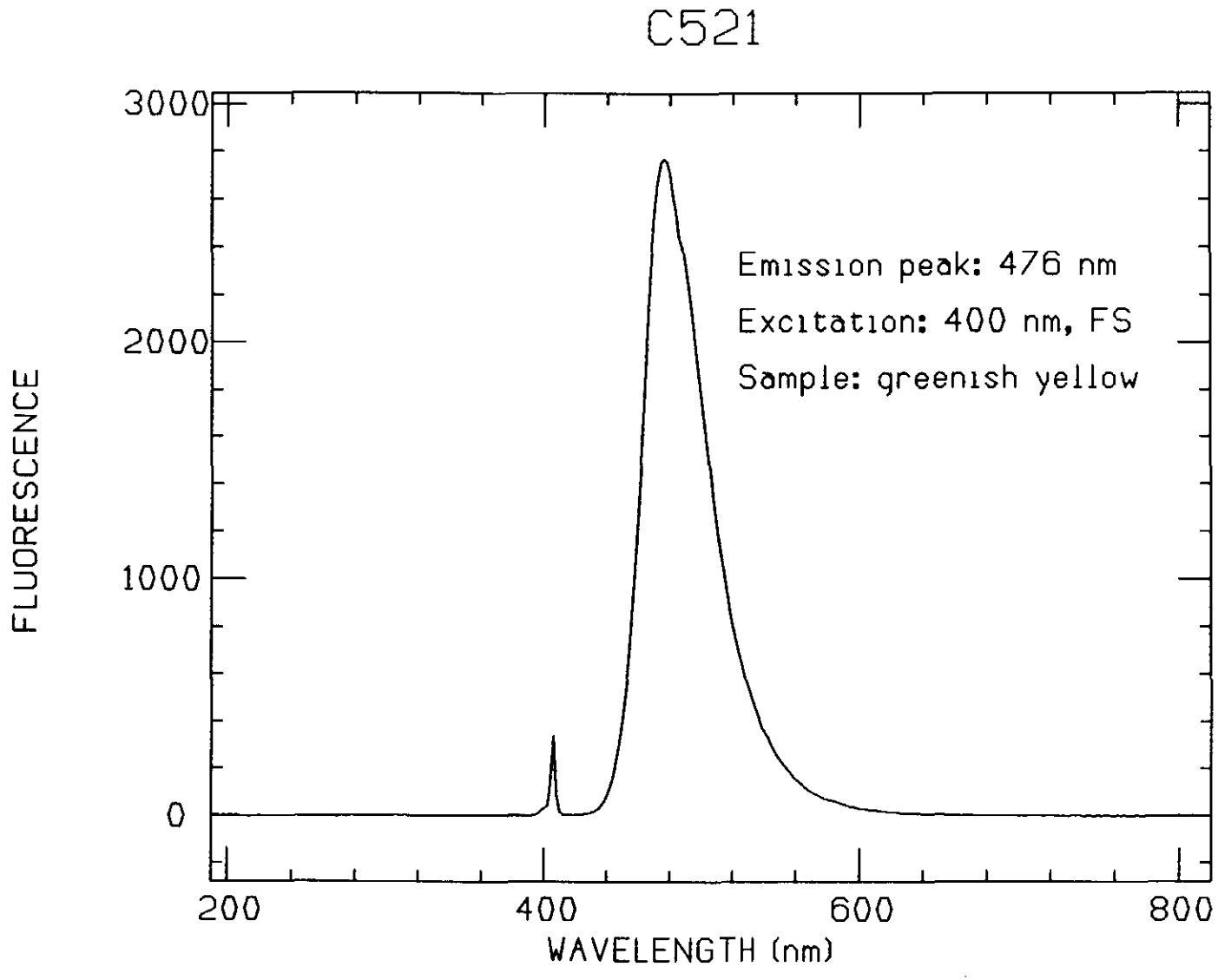

C515
FLUORESCENCE
300
200
100
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 478 nm
Excitation: 313 nm, FS
Sample: greenish yellow

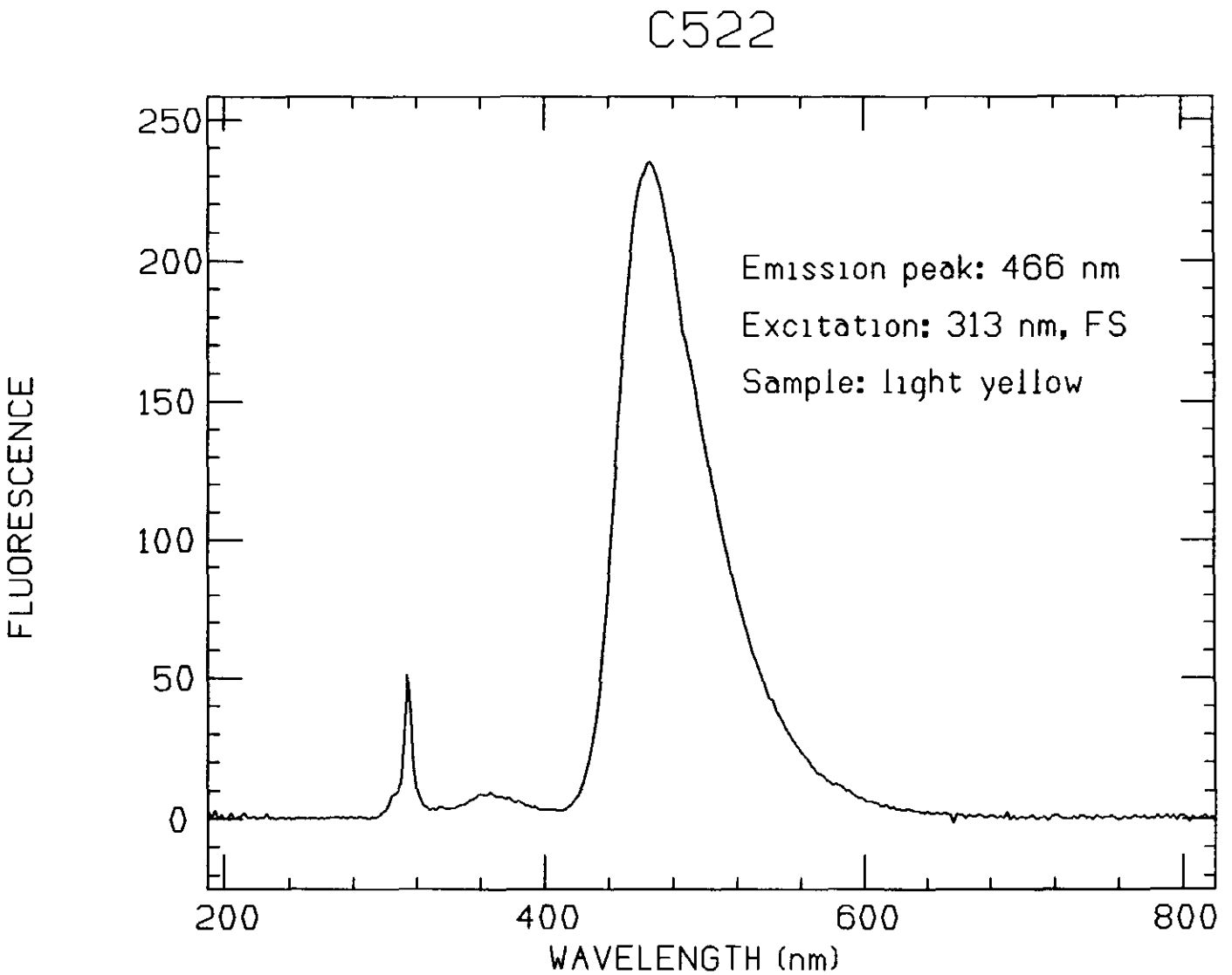

C515
FLUORESCENCE
1500
1000
500
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 478 nm
Excitation: 400 nm, FS
Sample: greenish yellow

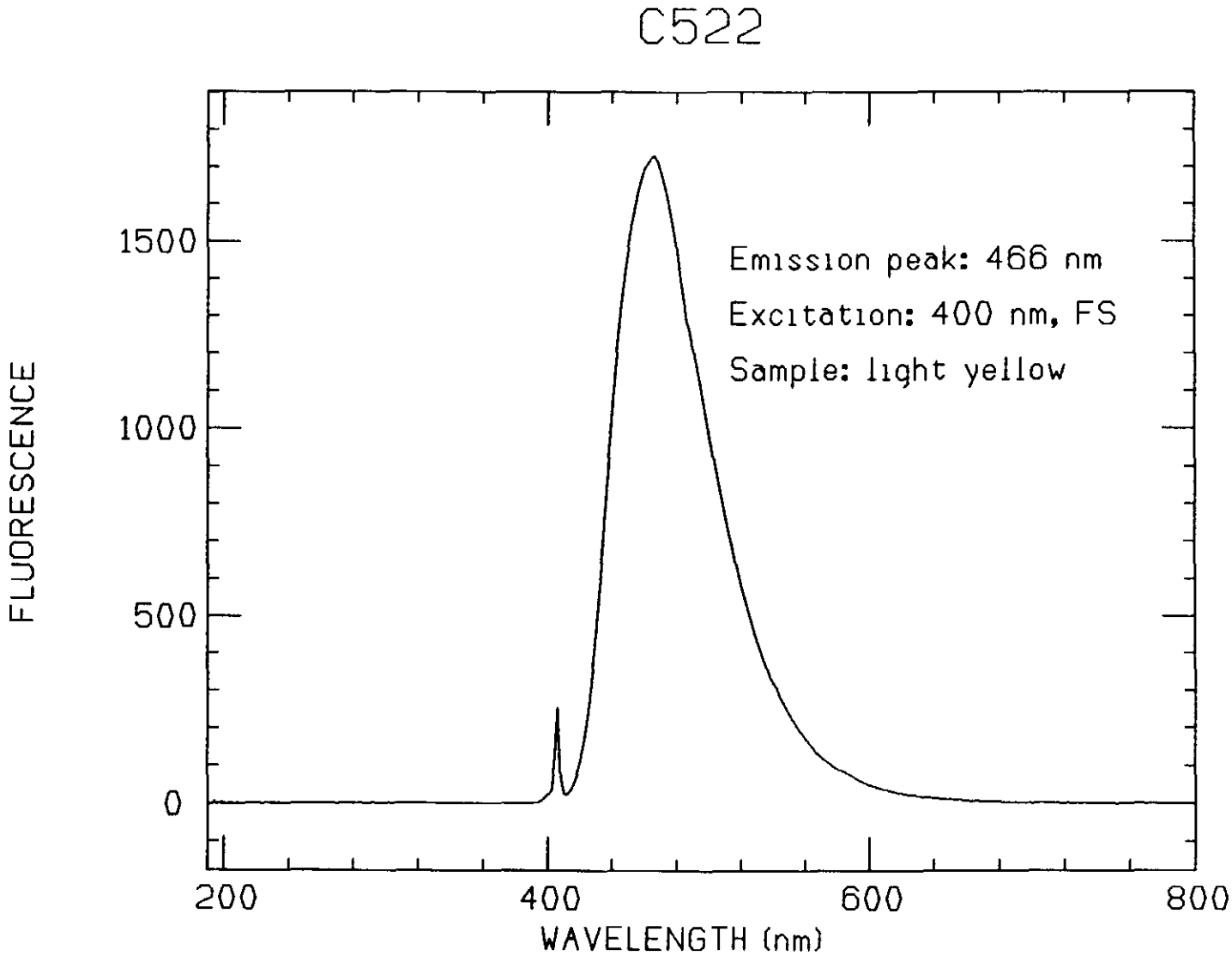

C519
FLUORESCENCE
300
200
100
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 476 nm
Excitation: 313 nm, FS
Sample: greenish yellow

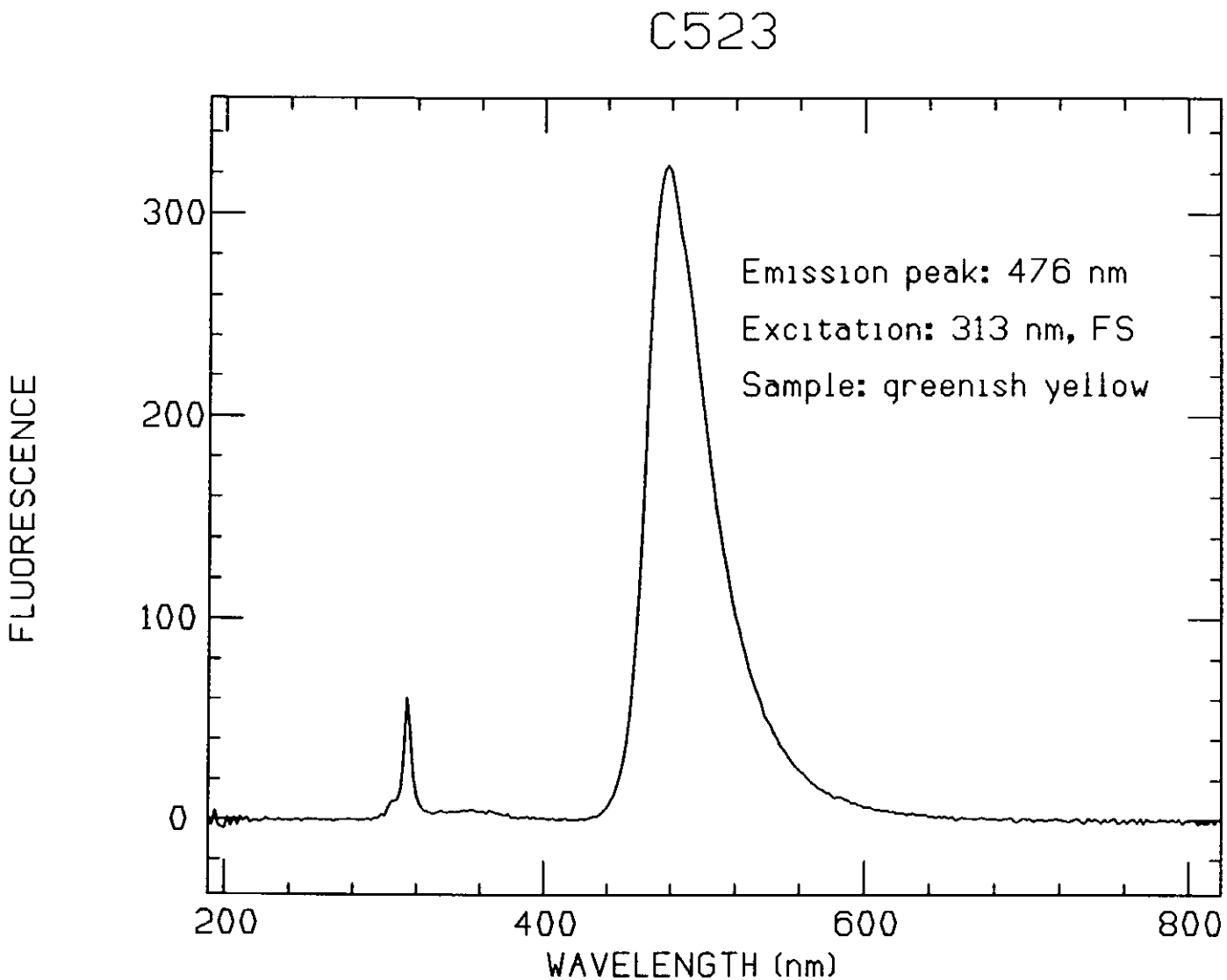

C519
3000
2000
1000
0
FLUORESCENCE
200
400
600
800
WAVELENGTH (nm)
Emission peak: 474 nm
Excitation: 400 nm, FS
Sample: greenish yellow

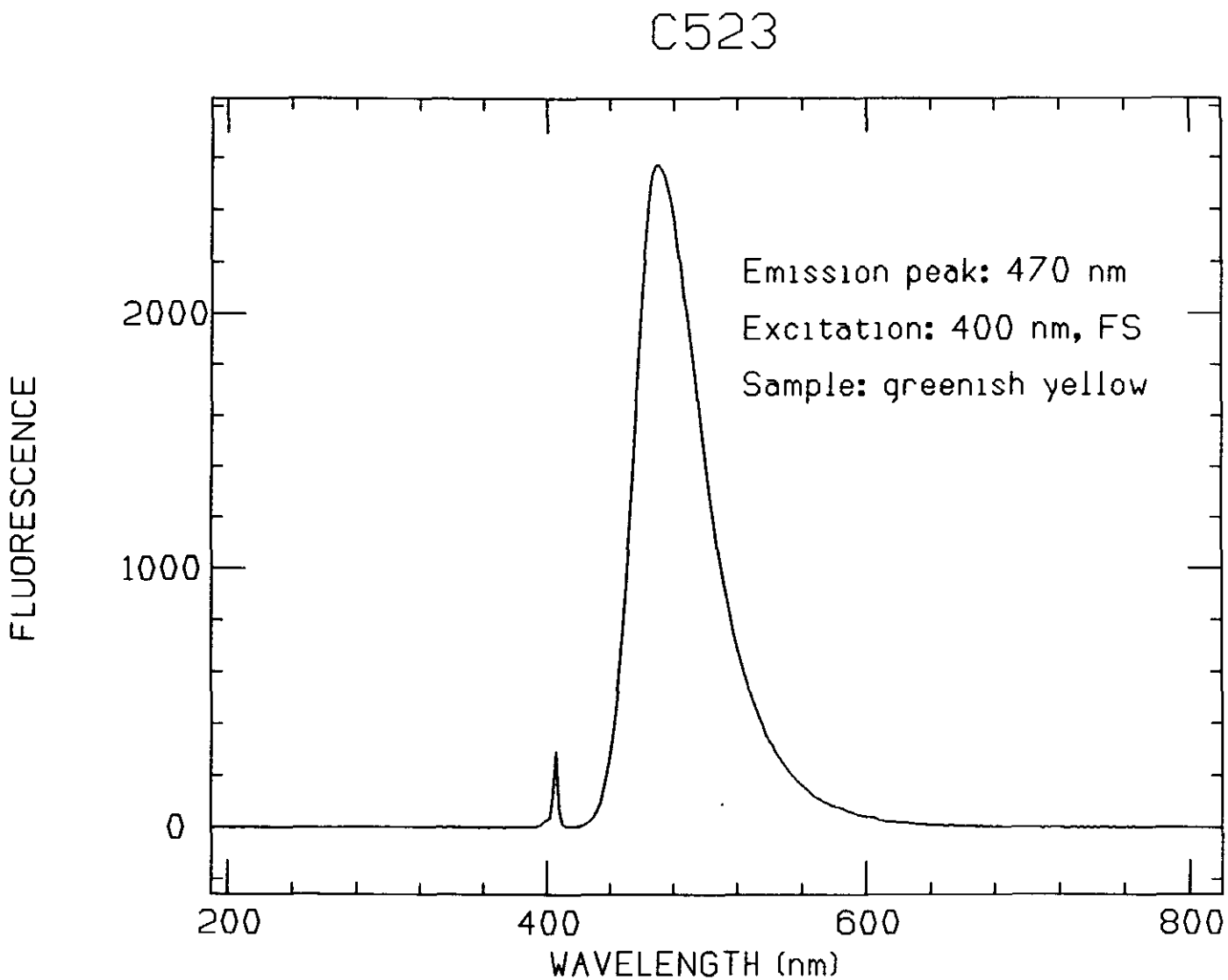

C521
FLUORESCENCE
300
200
100
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 476 nm
Excitation: 313 nm, FS
Sample: greenish yellow

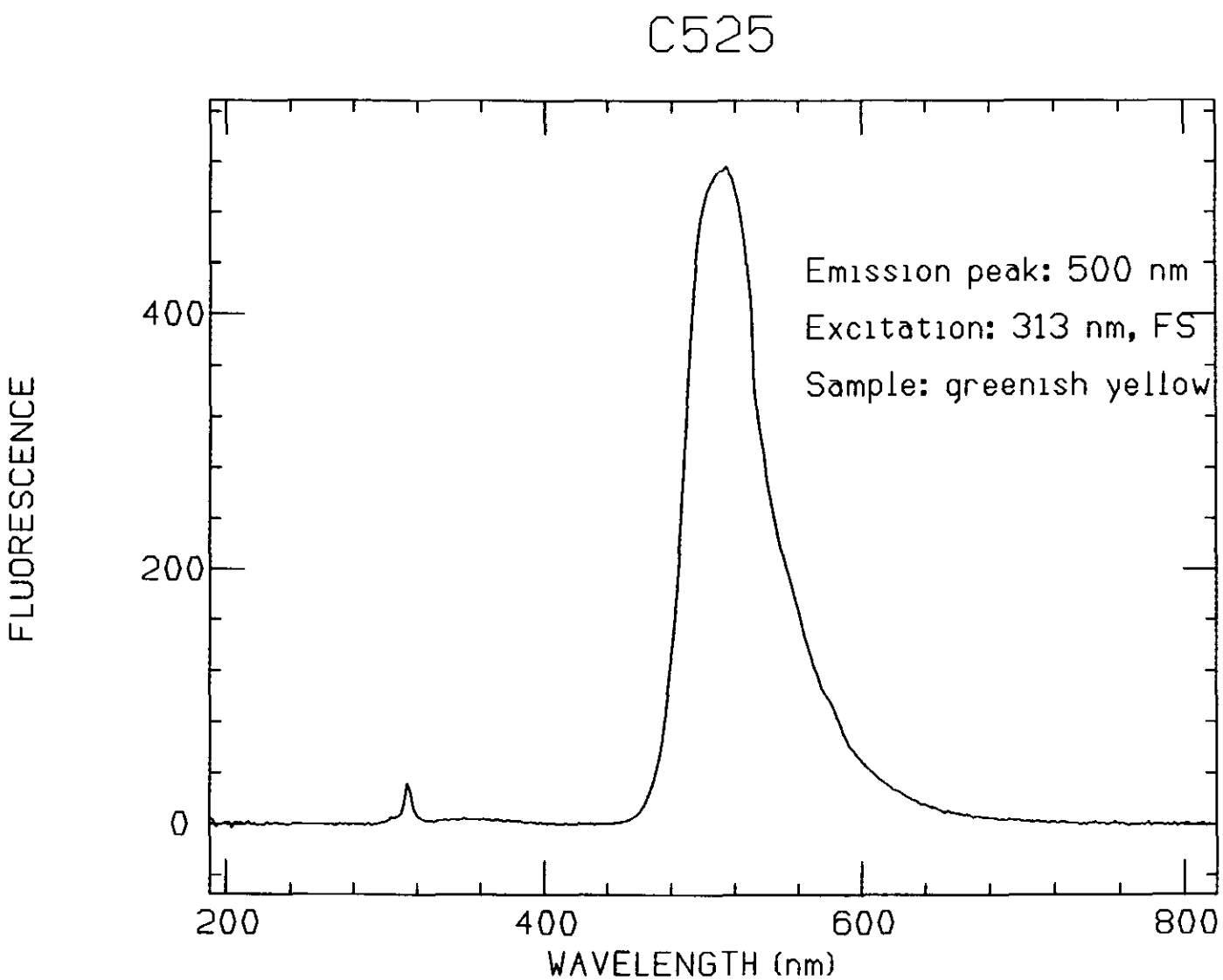

C521
3000
2000
1000
0
FLUORESCENCE
200
400
600
800
WAVELENGTH (nm)
Emission peak: 476 nm
Excitation: 400 nm, FS
Sample: greenish yellow

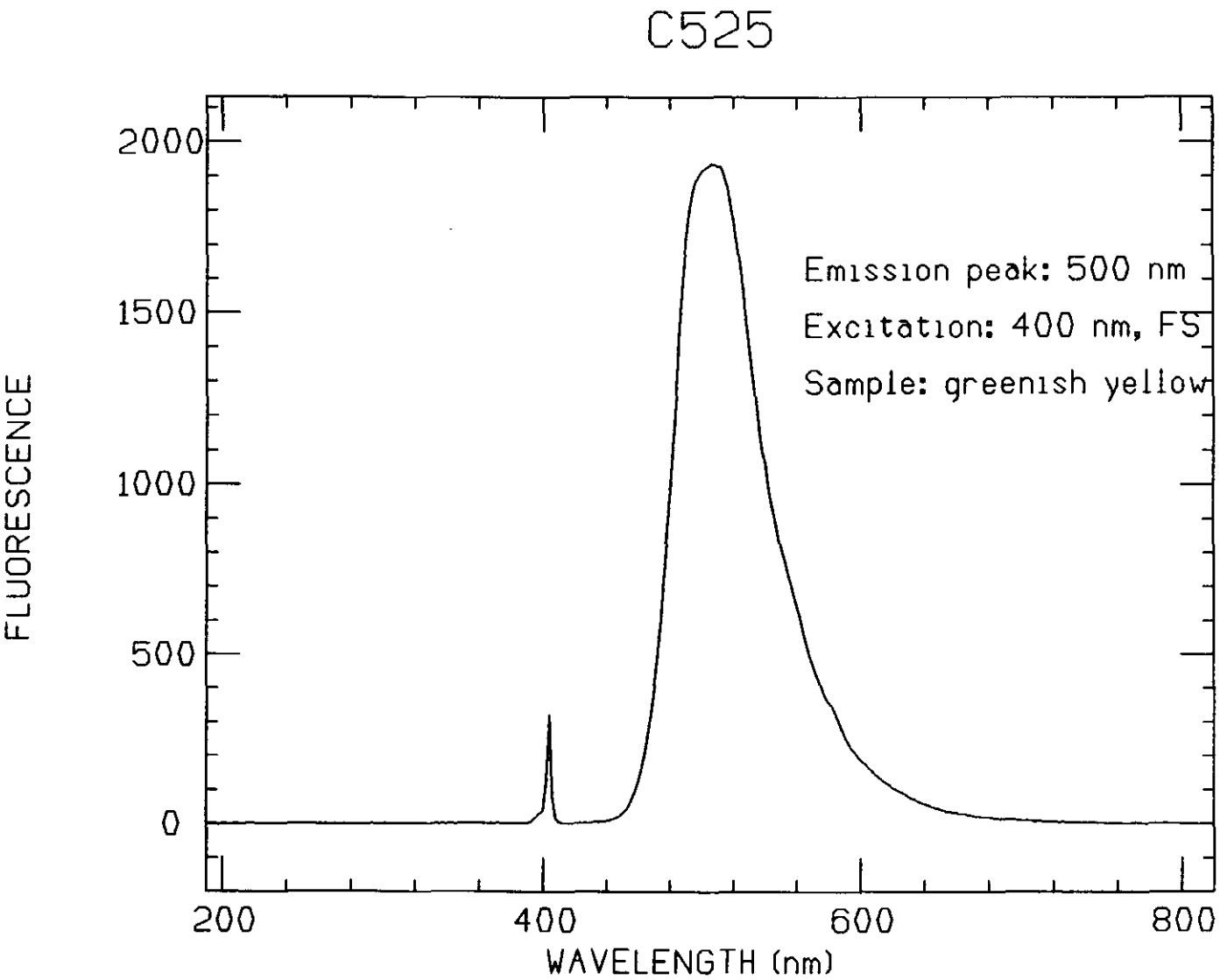

C522
FLUORESCENCE
250
200
150
100
50
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 466 nm
Excitation: 313 nm, FS
Sample: light yellow

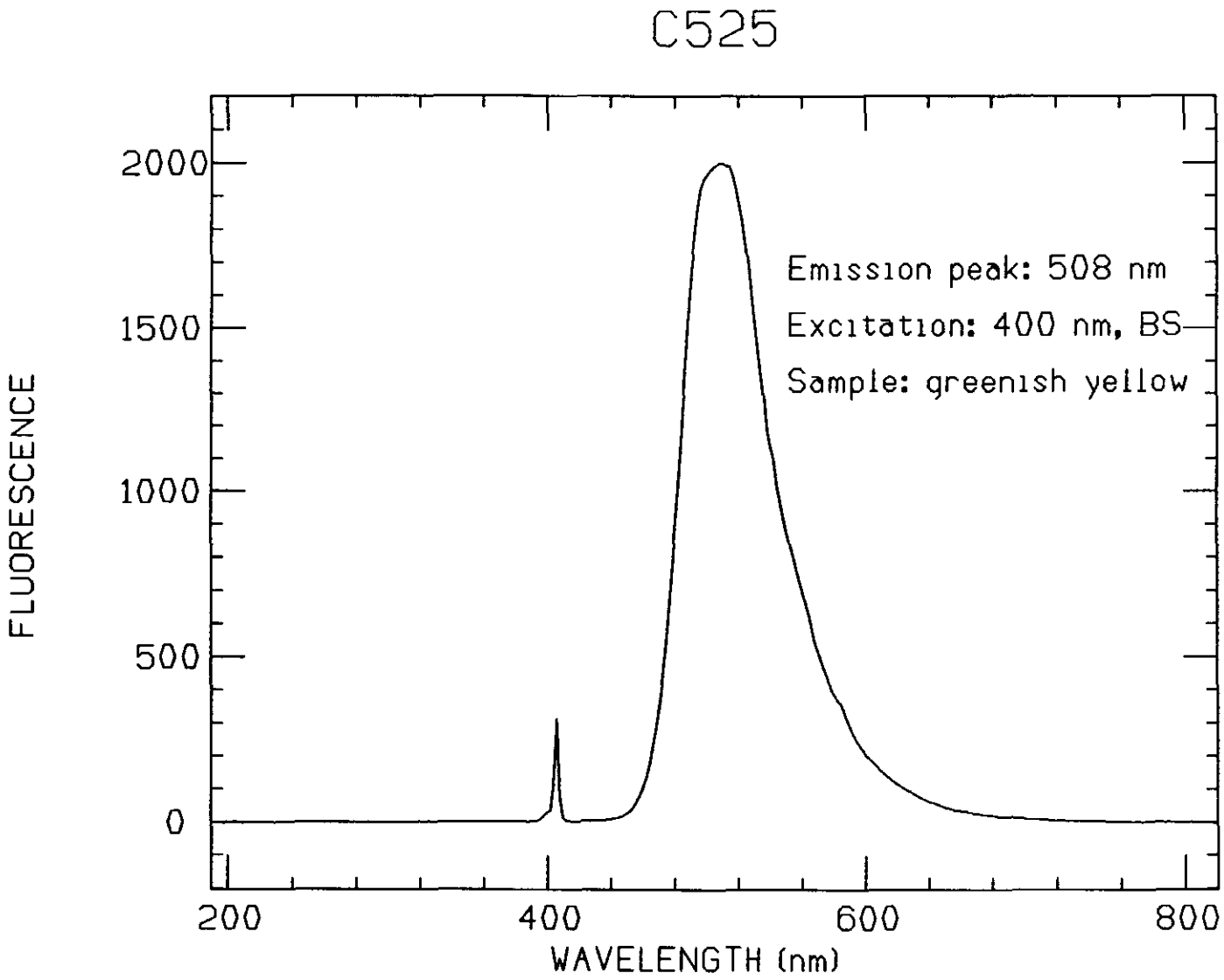

C522
FLUORESCENCE
1500
1000
500
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 466 nm
Excitation: 400 nm, FS
Sample: light yellow

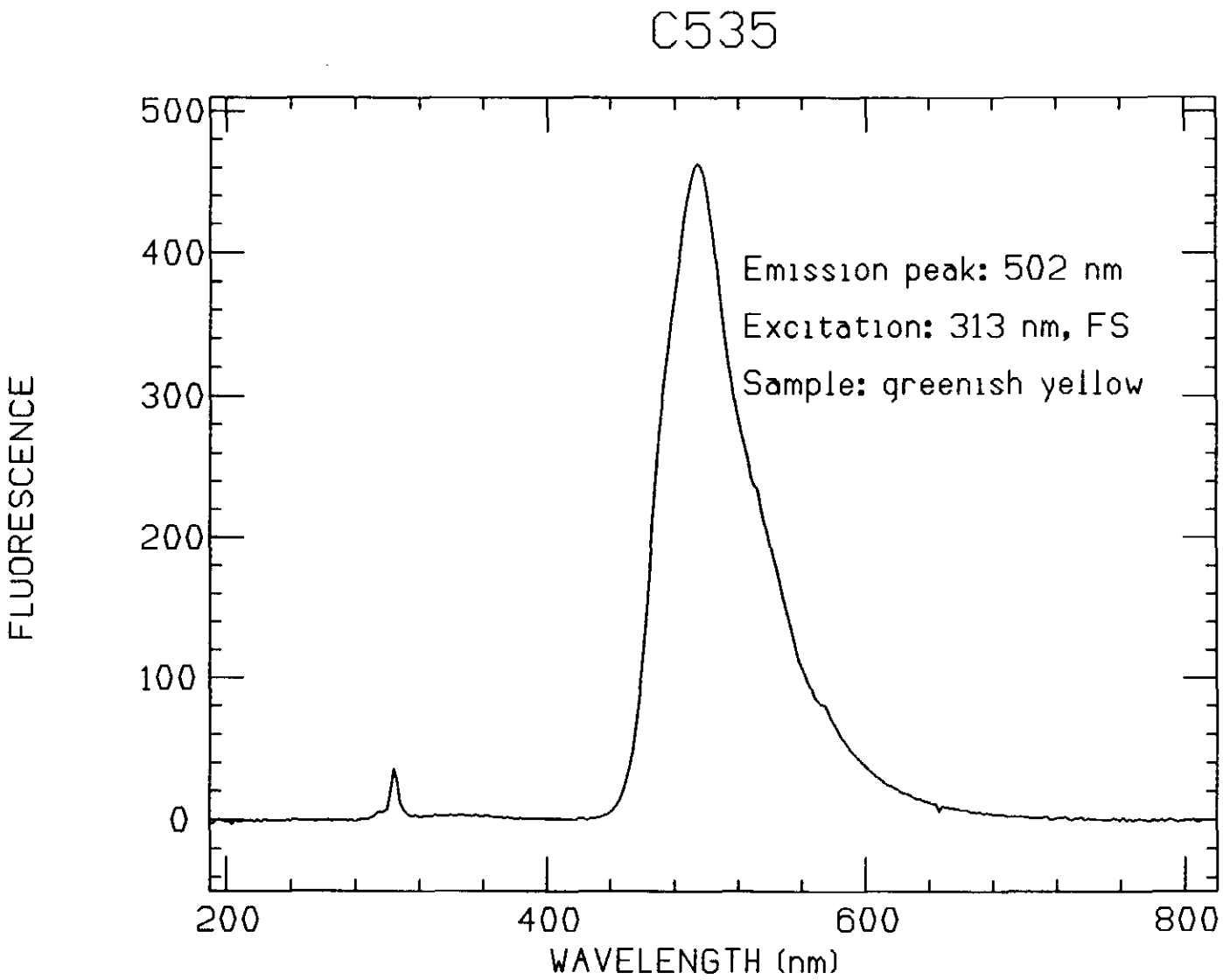

C523
FLUORESCENCE
300
200
100
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 476 nm
Excitation: 313 nm, FS
Sample: greenish yellow

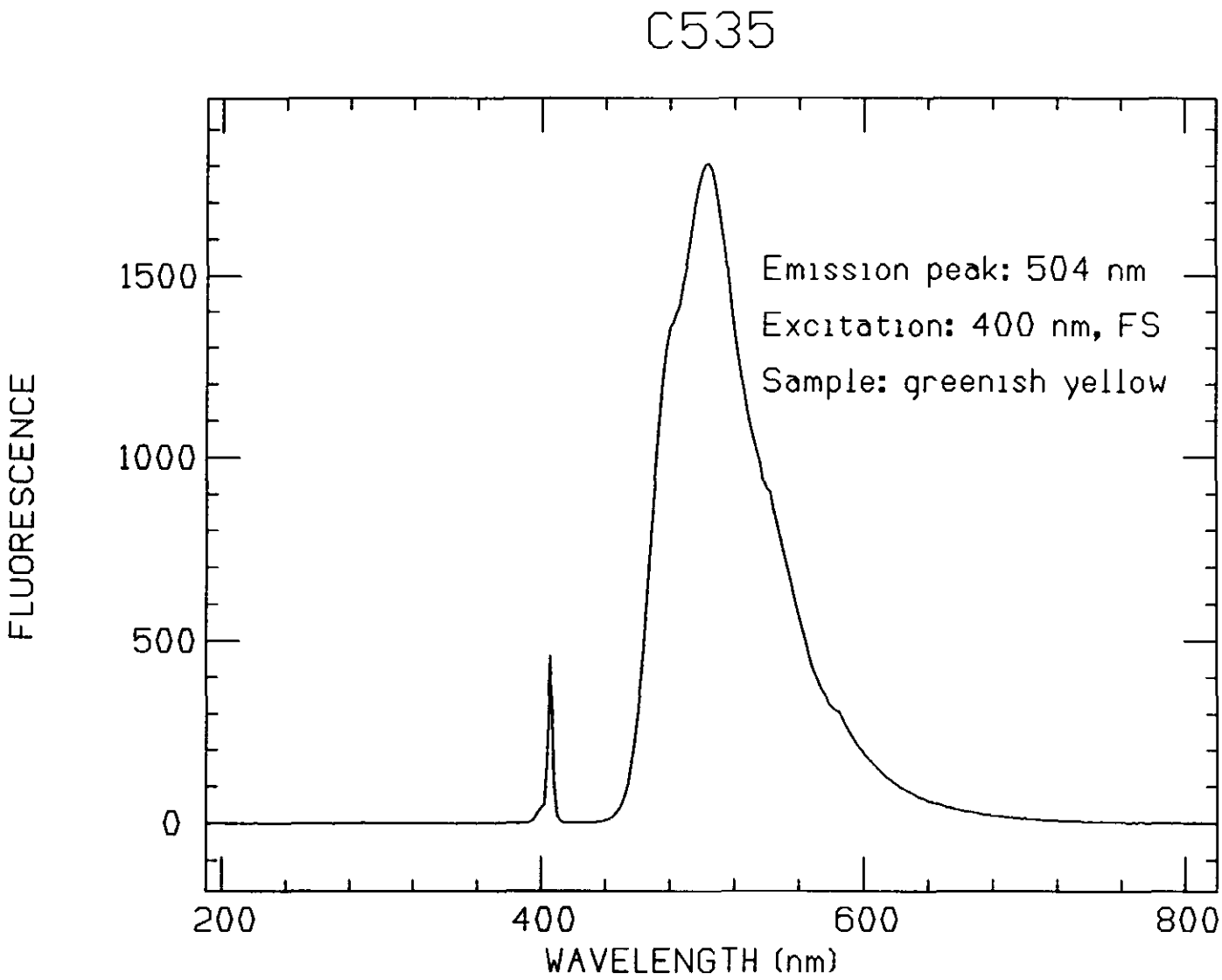

C523
Emission peak: 470 nm
Excitation: 400 nm, FS
Sample: greenish yellow
FLUORESCENCE
2000
1000
0
200
400
600
800
WAVELENGTH (nm)

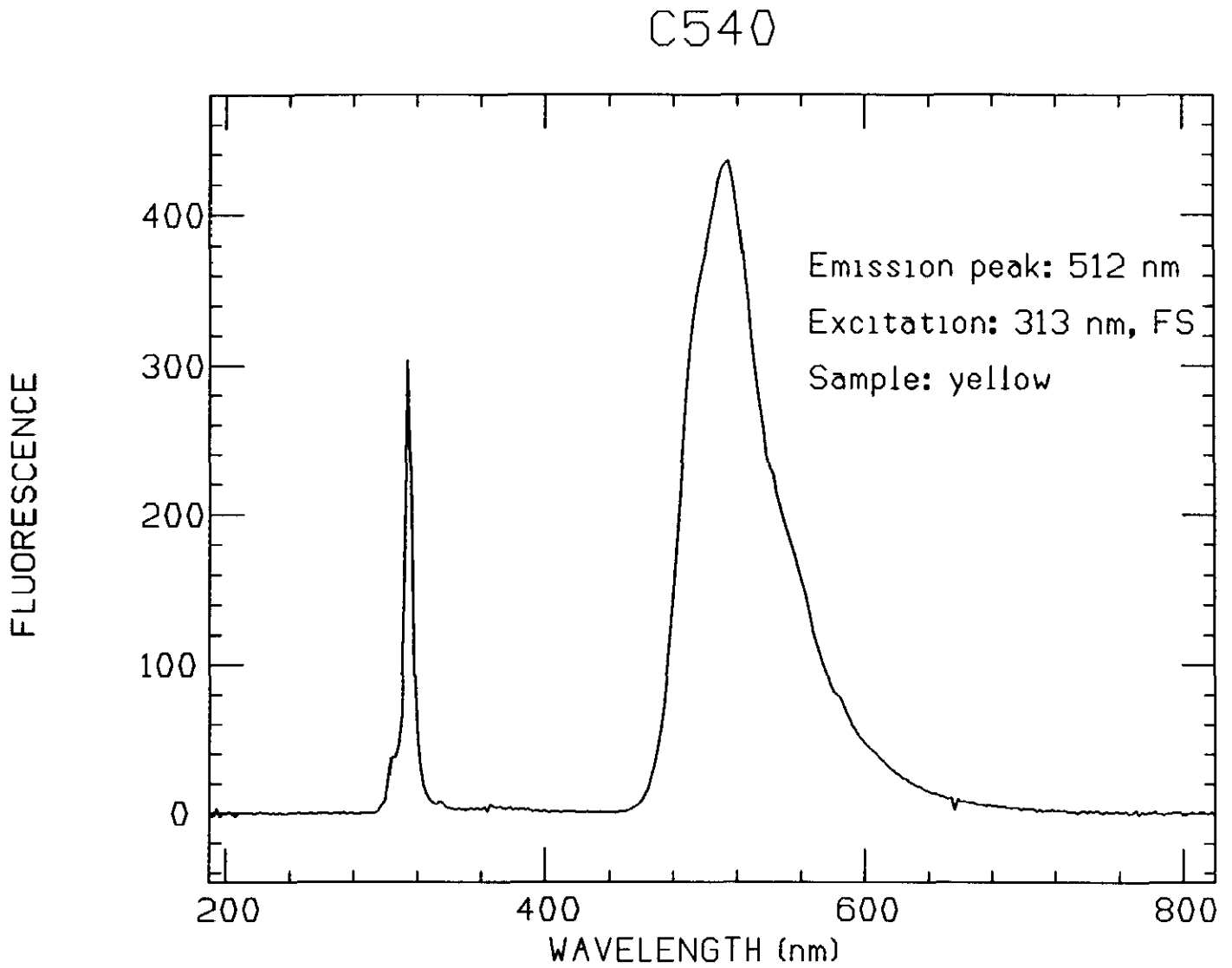

C525
Emission peak: 500 nm
Excitation: 313 nm, FS
Sample: greenish yellow
FLUORESCENCE
0
200
400
200
400
600
800
WAVELENGTH (nm)

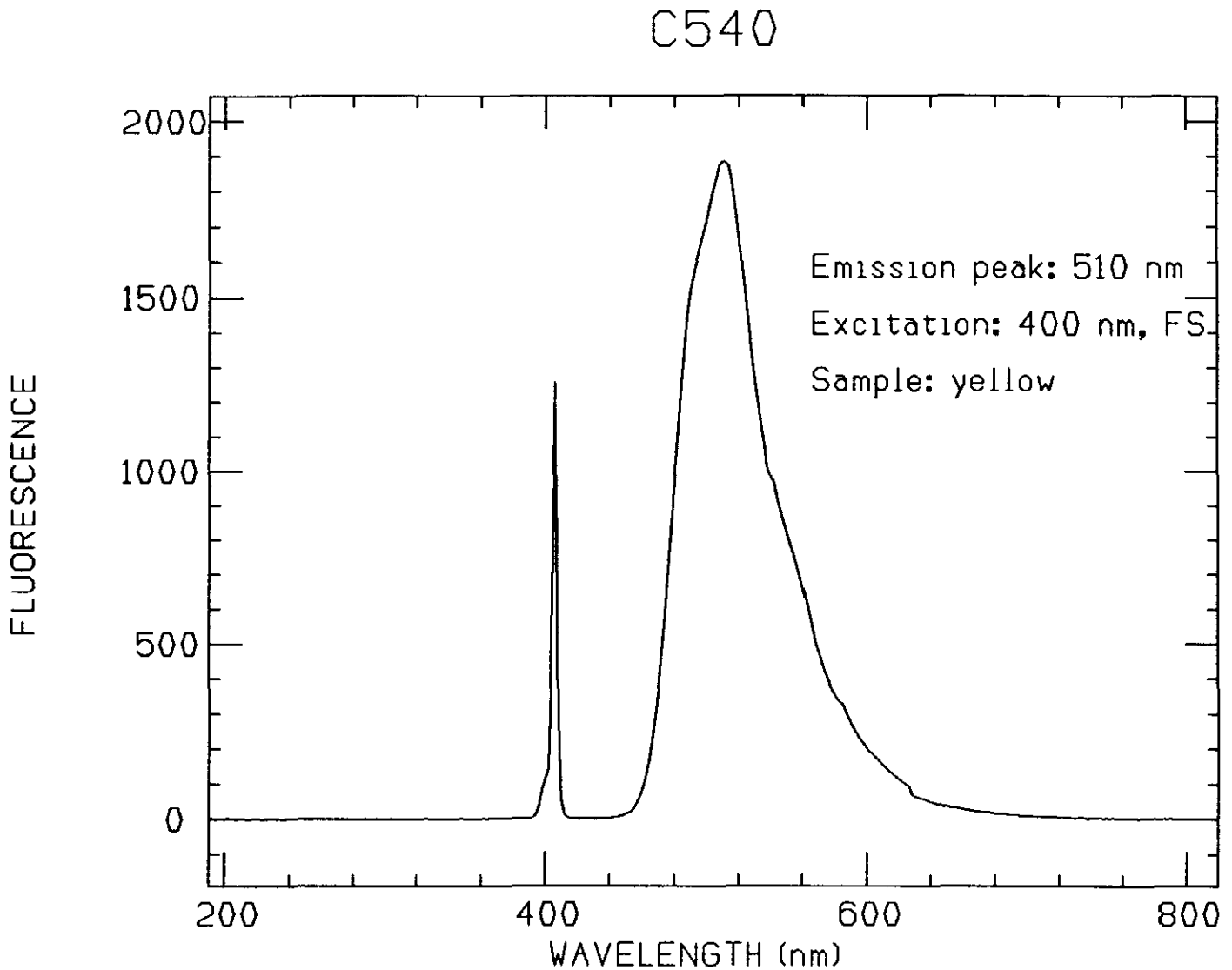

C525
FLUORESCENCE
2000
1500
1000
500
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 500 nm
Excitation: 400 nm, FS
Sample: greenish yellow

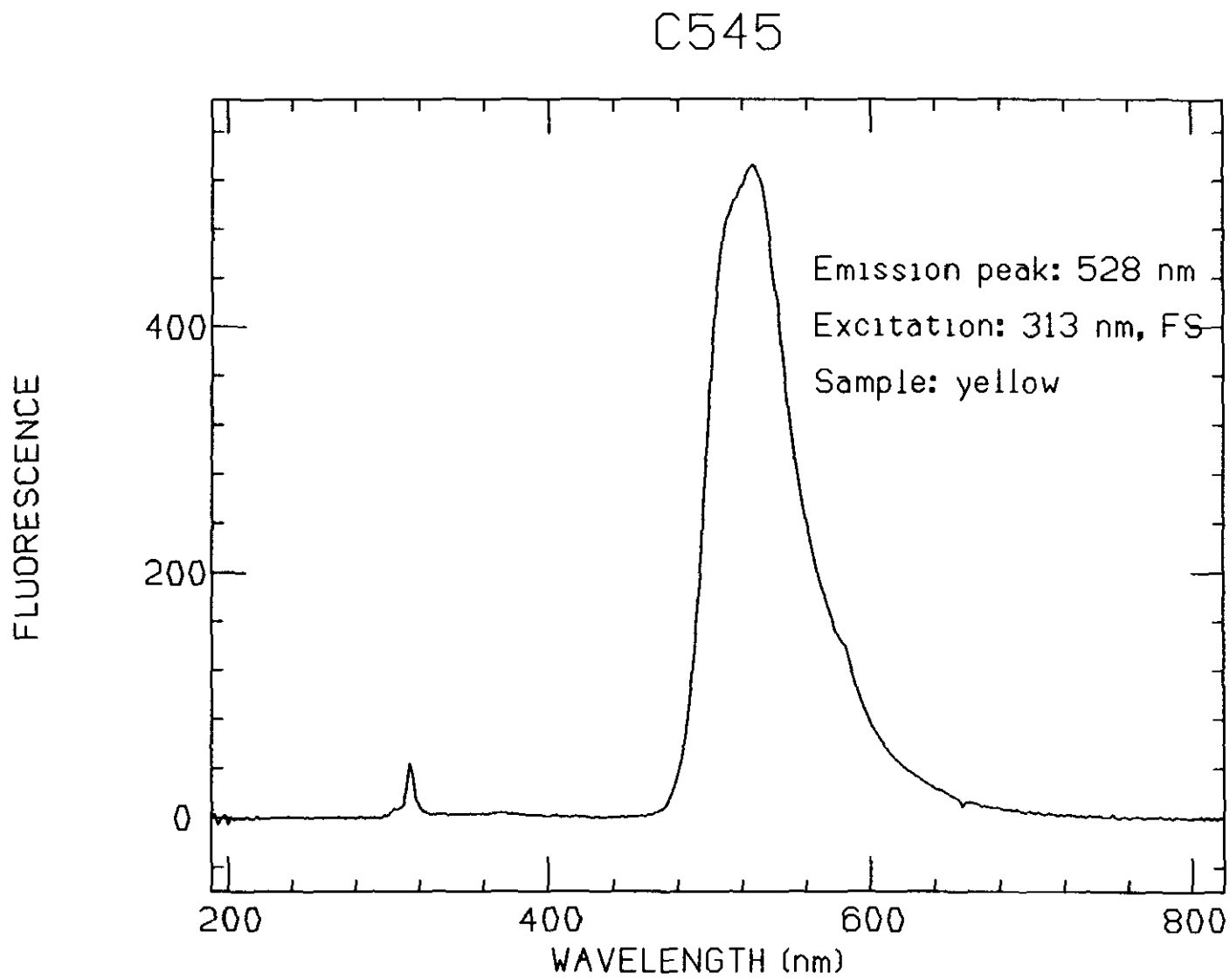

C525
FLUORESCENCE
2000
1500
1000
500
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 508 nm
Excitation: 400 nm, BS
Sample: greenish yellow

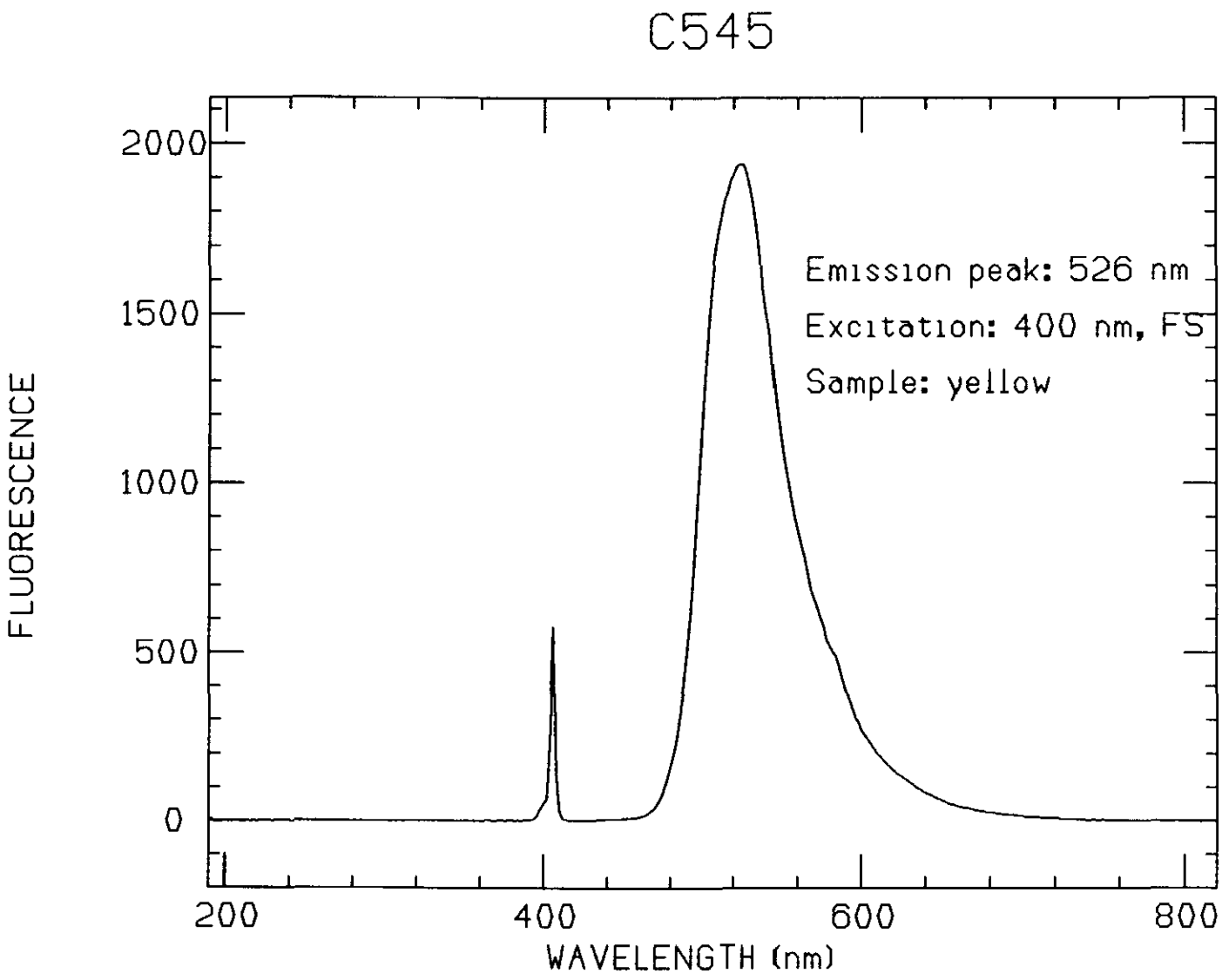

C535
FLUORESCENCE
500
400
300
200
100
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 502 nm
Excitation: 313 nm, FS
Sample: greenish yellow


C535
Emission peak: 504 nm
Excitation: 400 nm, FS
Sample: greenish yellow
FLUORESCENCE
1500
1000
500
0
200
400
600
800
WAVELENGTH (nm)

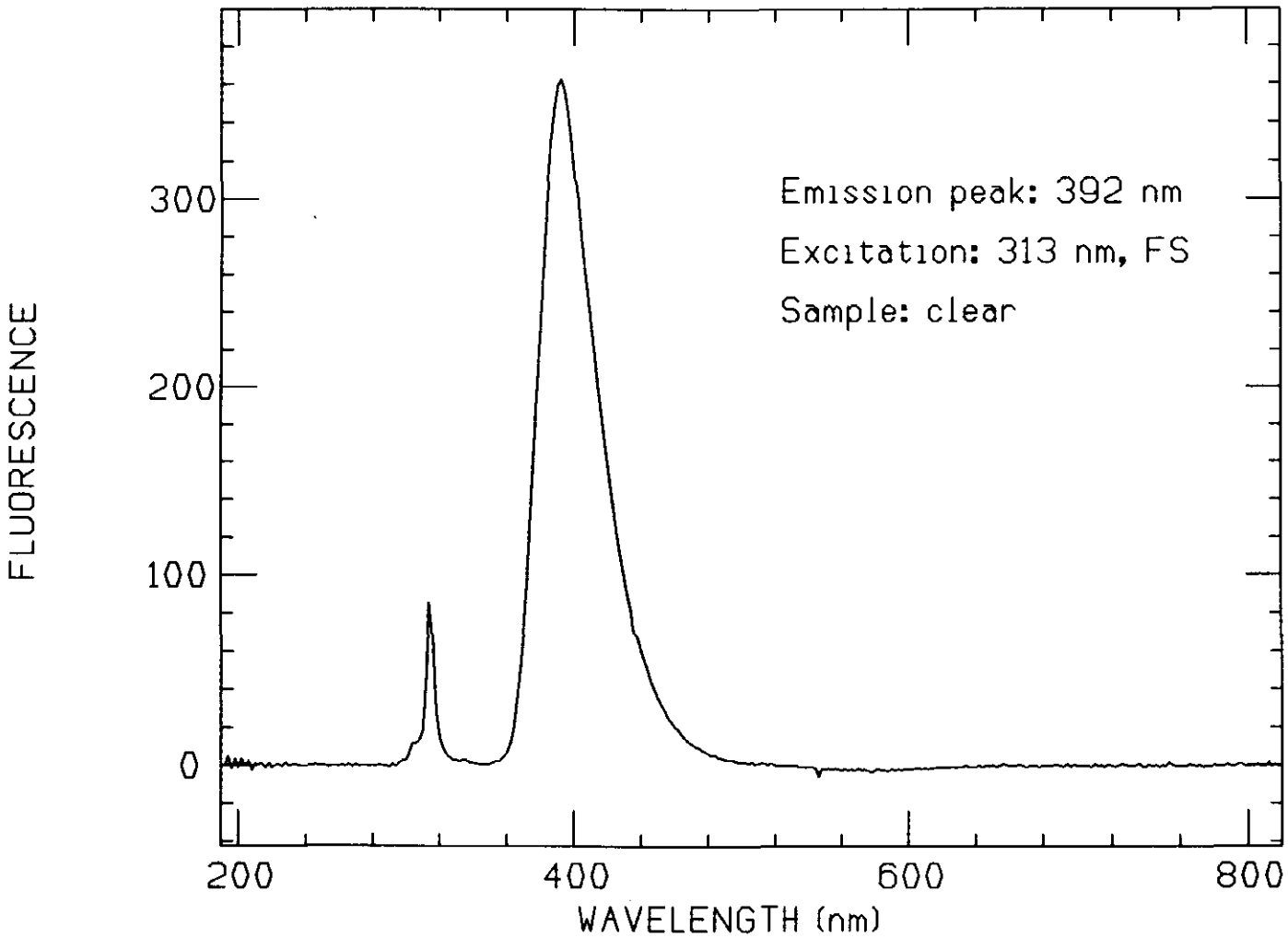

C540
FLUORESCENCE
400
300
200
100
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 512 nm
Excitation: 313 nm, FS
Sample: yellow

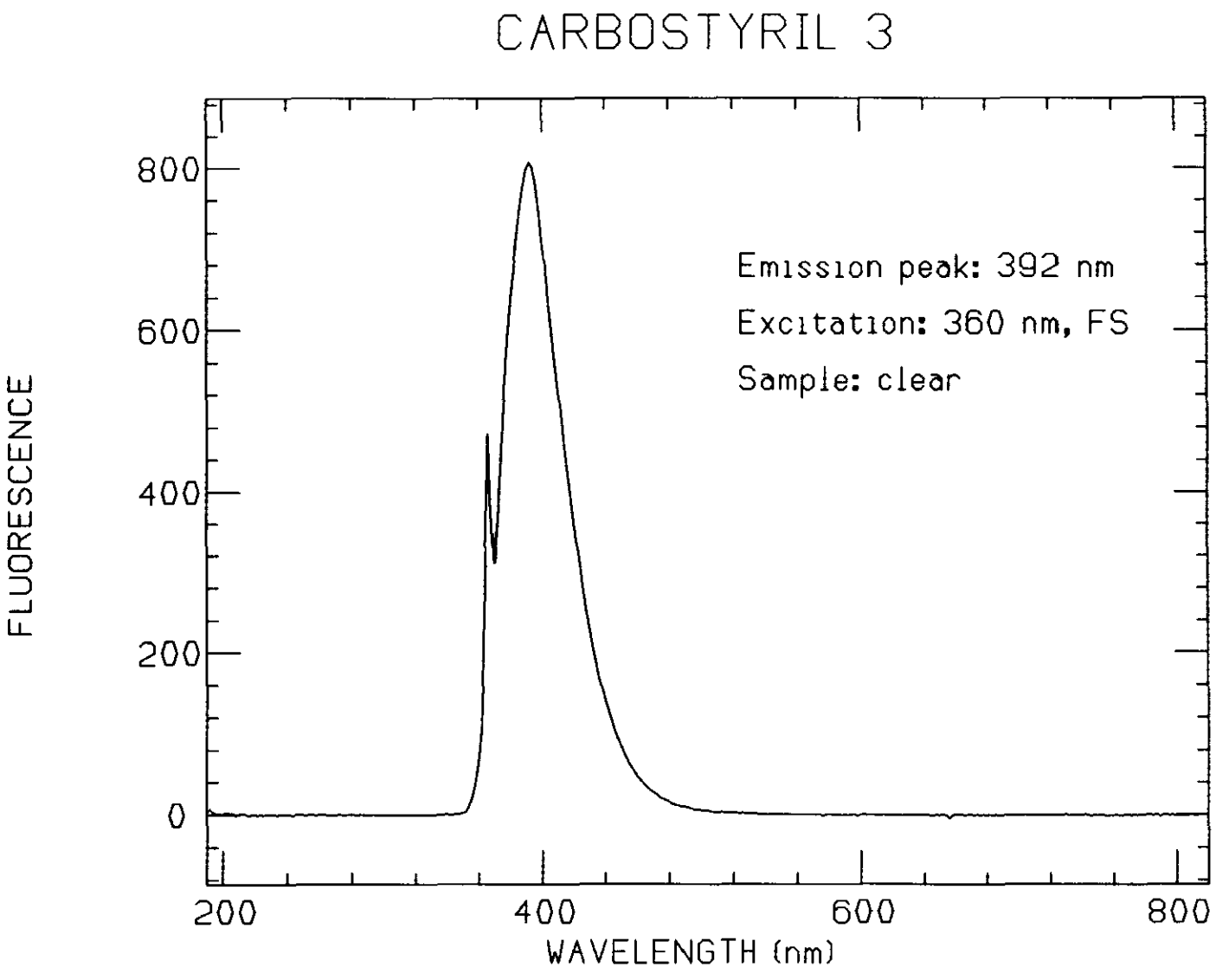

C540
2000
1500
1000
500
0
FLUORESCENCE
200
400
600
800
WAVELENGTH (nm)
Emission peak: 510 nm
Excitation: 400 nm, FS
Sample: yellow

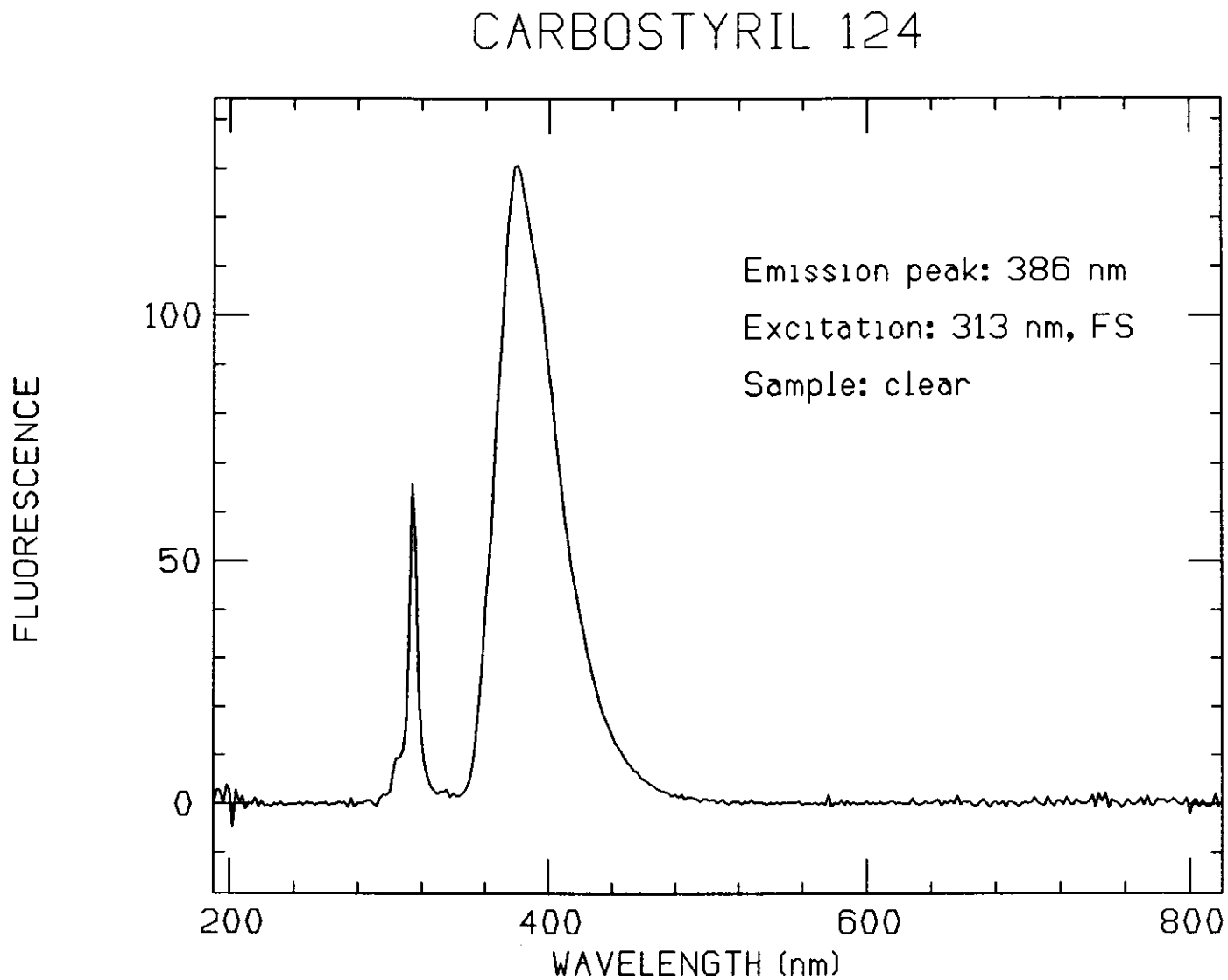

C545
FLUORESCENCE
400
200
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 528 nm
Excitation: 313 nm, FS
Sample: yellow

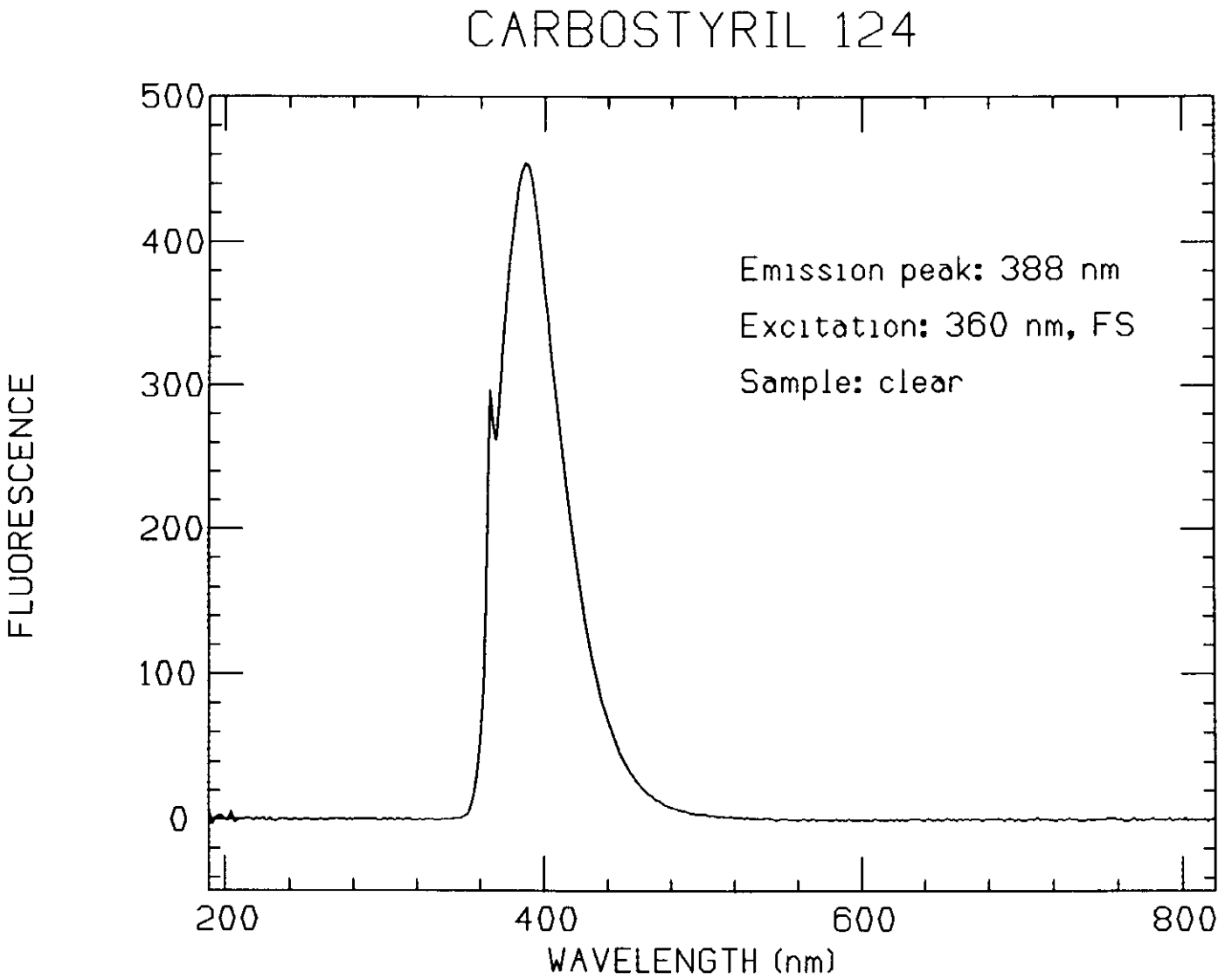

C545
FLUORESCENCE
2000
1500
1000
500
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 526 nm
Excitation: 400 nm, FS
Sample: yellow

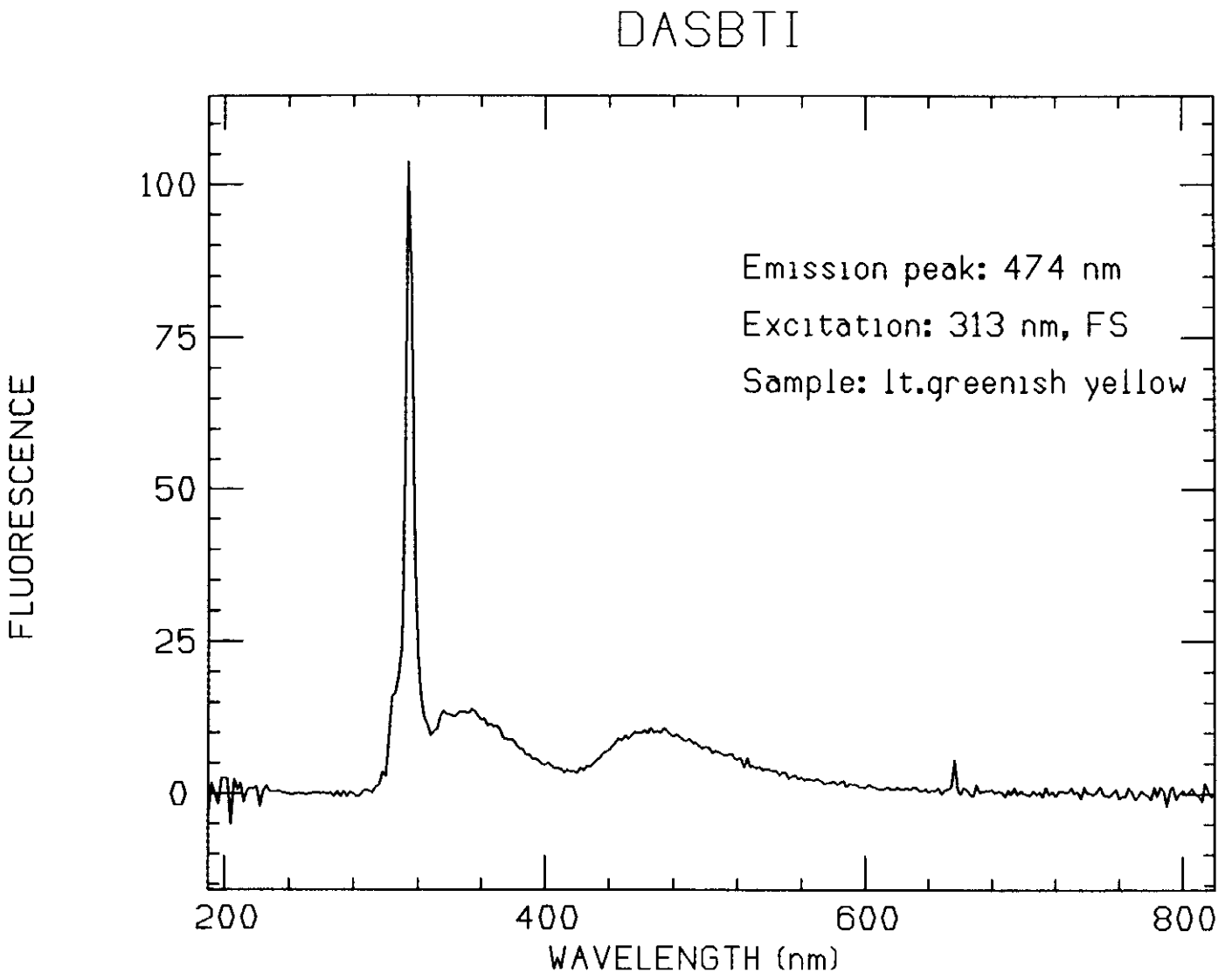
CARBOSTYRIL 3

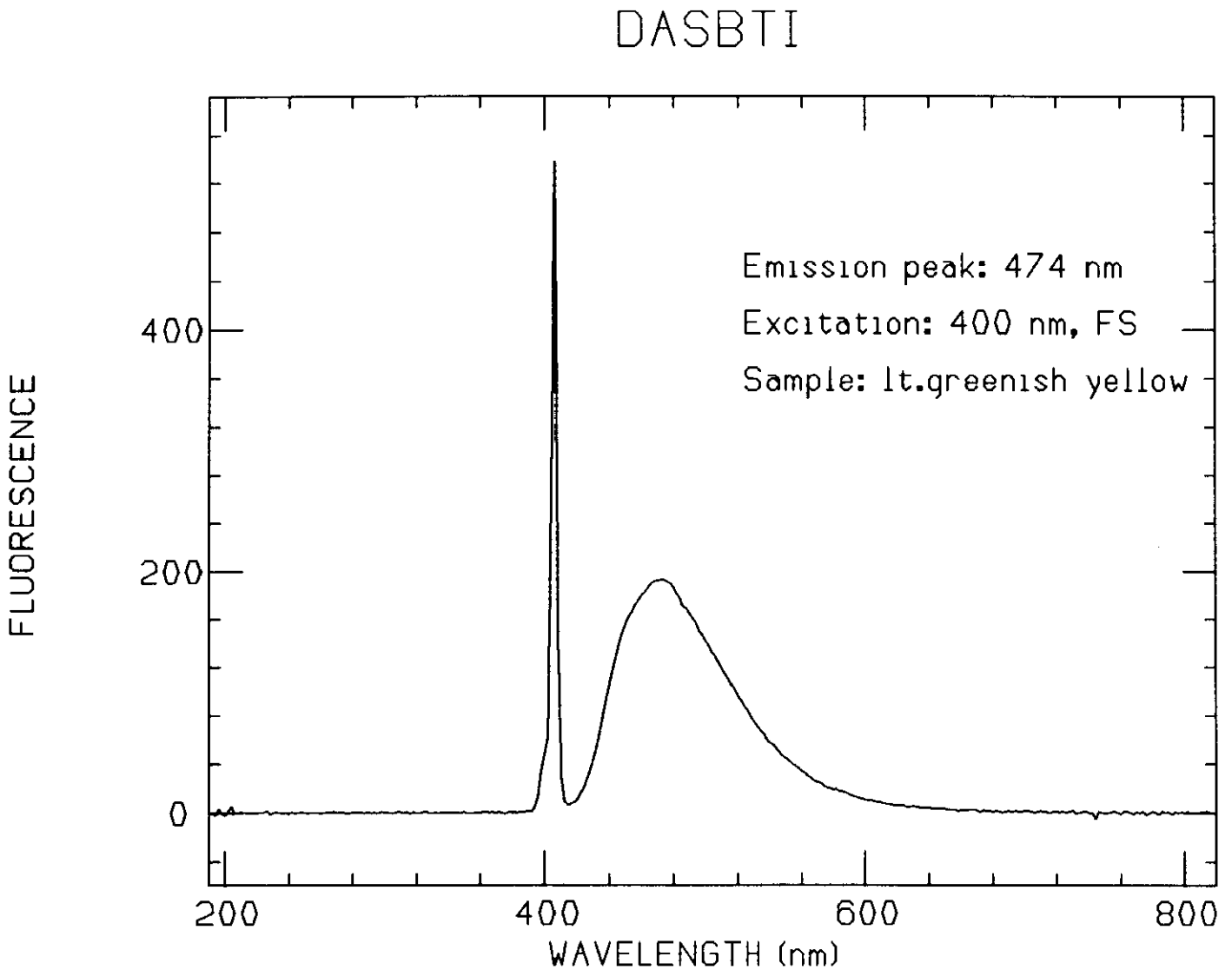


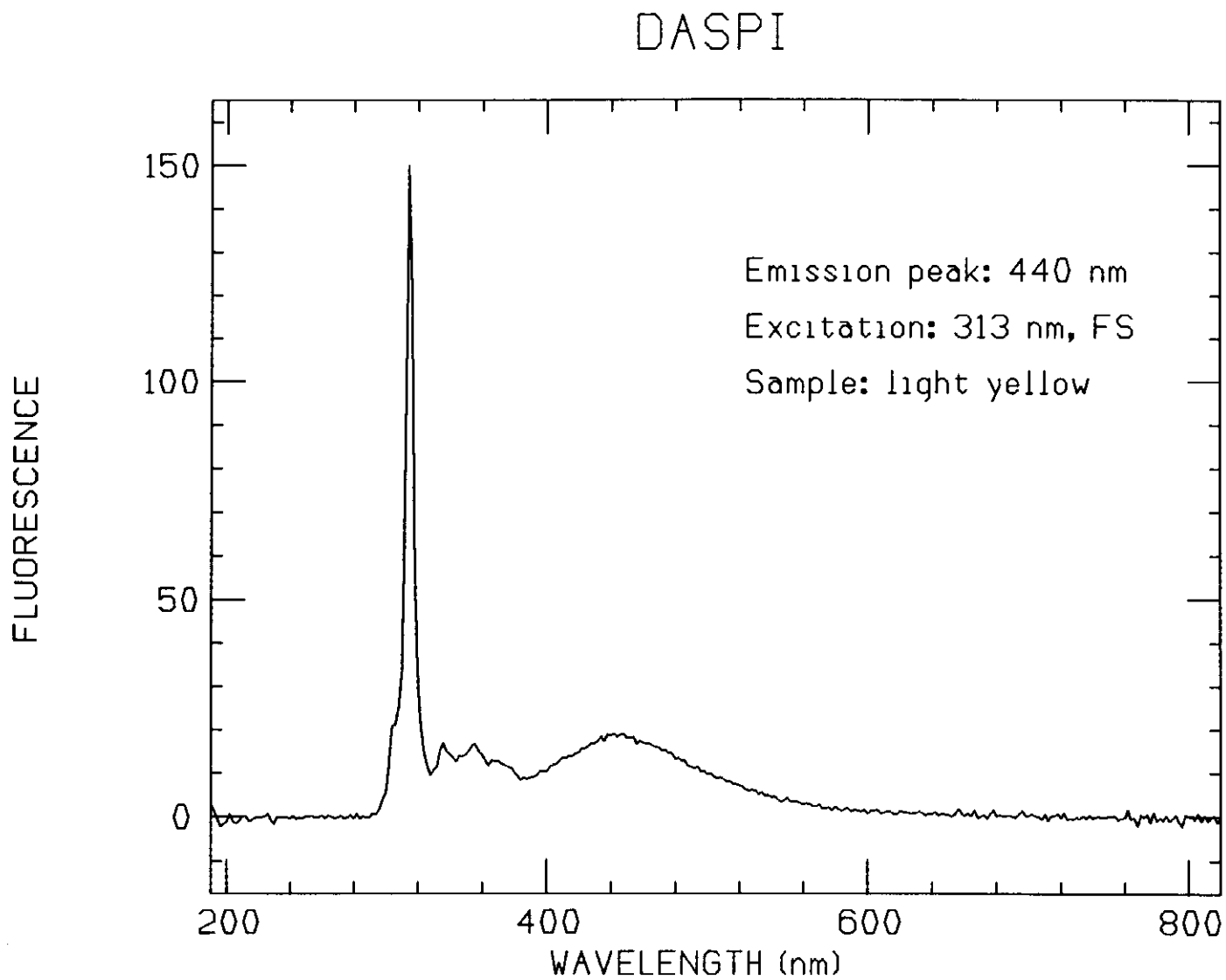

CARBOSTYRIL 3
FLUORESCENCE
800
600
400
200
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 392 nm
Excitation: 360 nm, FS
Sample: clear

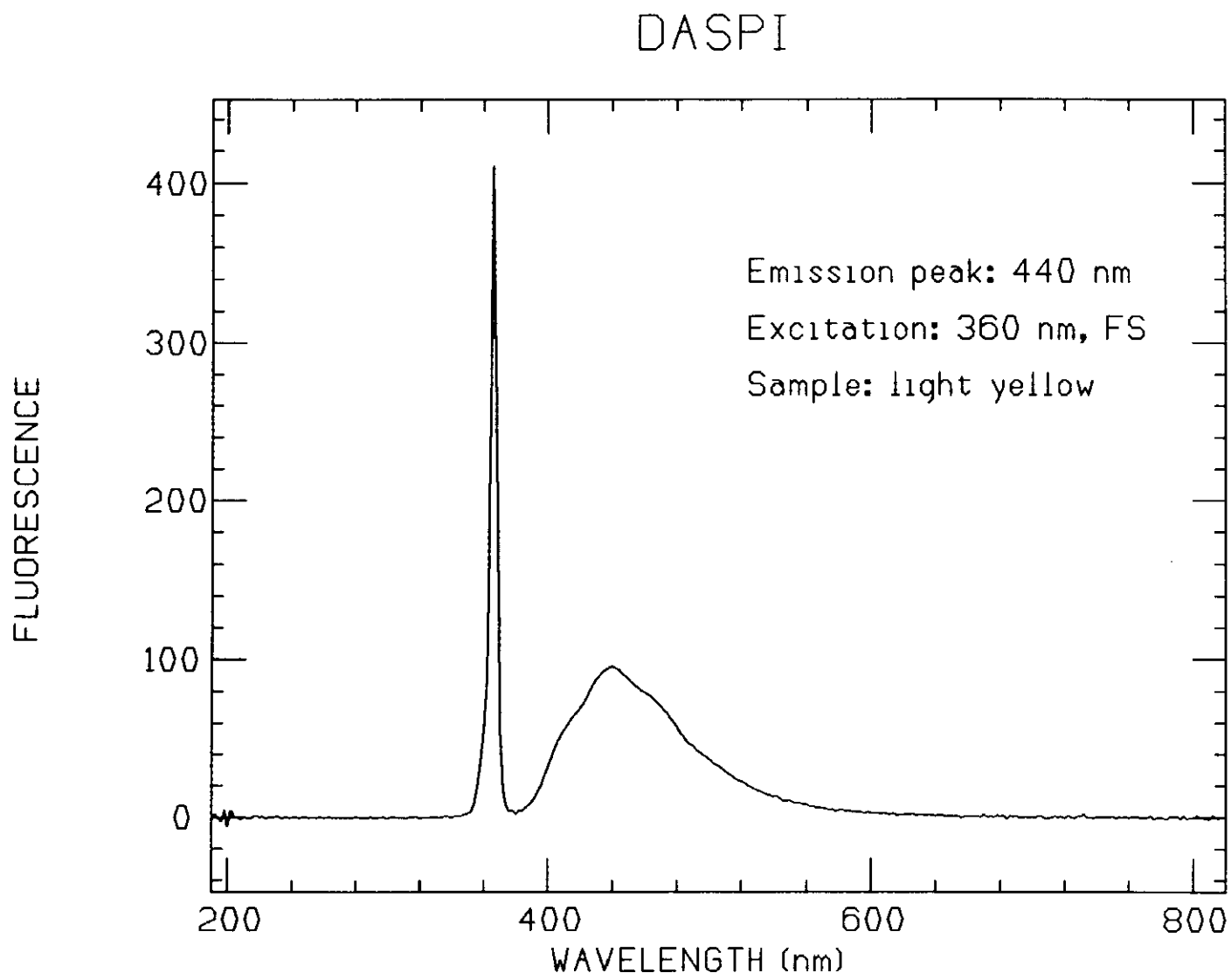

CARBOSTYRIL 124
Emission peak: 386 nm
Excitation: 313 nm, FS
Sample: clear
FLUORESCENCE
100
50
0
200
400
600
800
WAVELENGTH (nm)

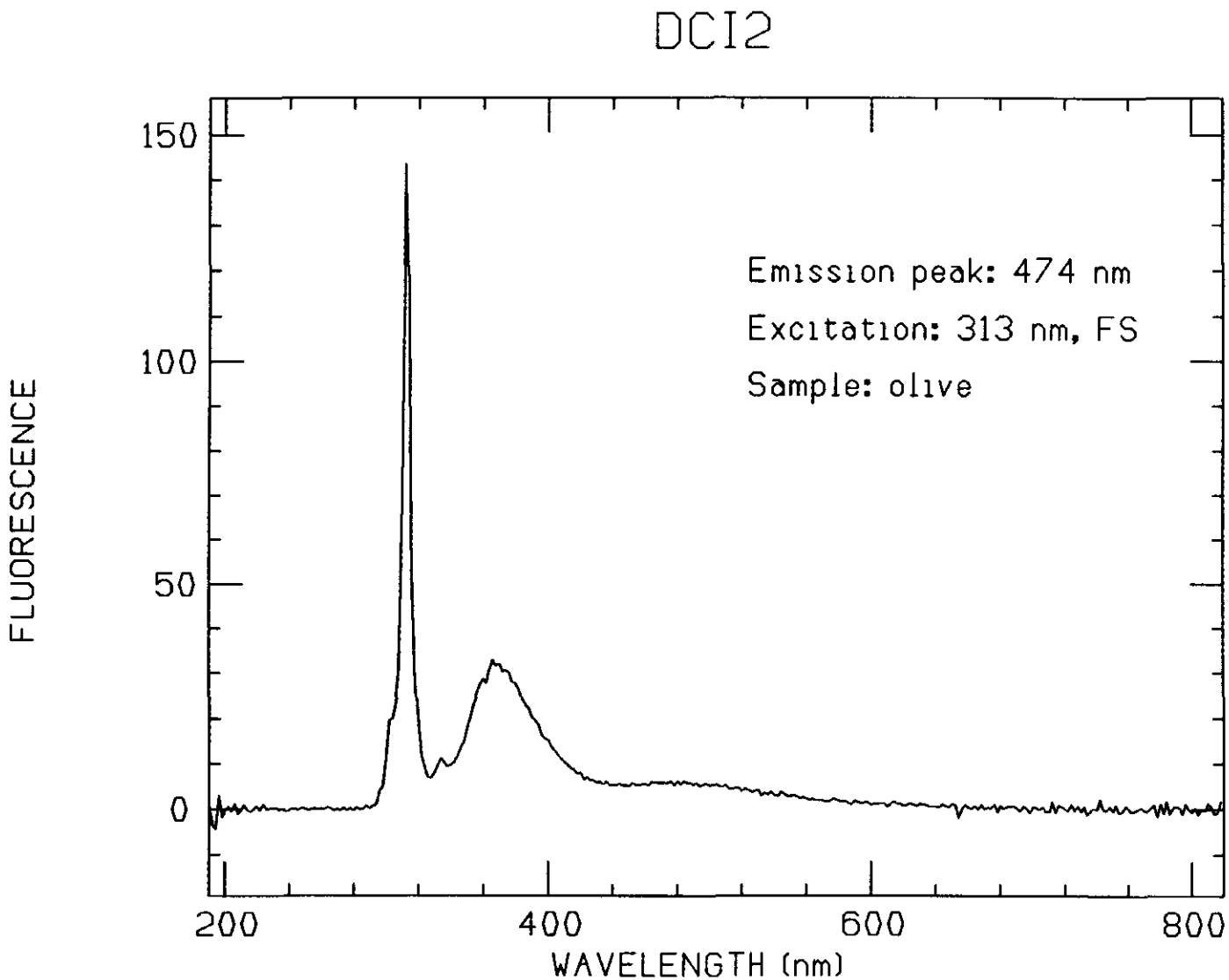

CARBOSTYRIL 124
FLUORESCENCE
500
400
300
200
100
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 388 nm
Excitation: 360 nm, FS
Sample: clear

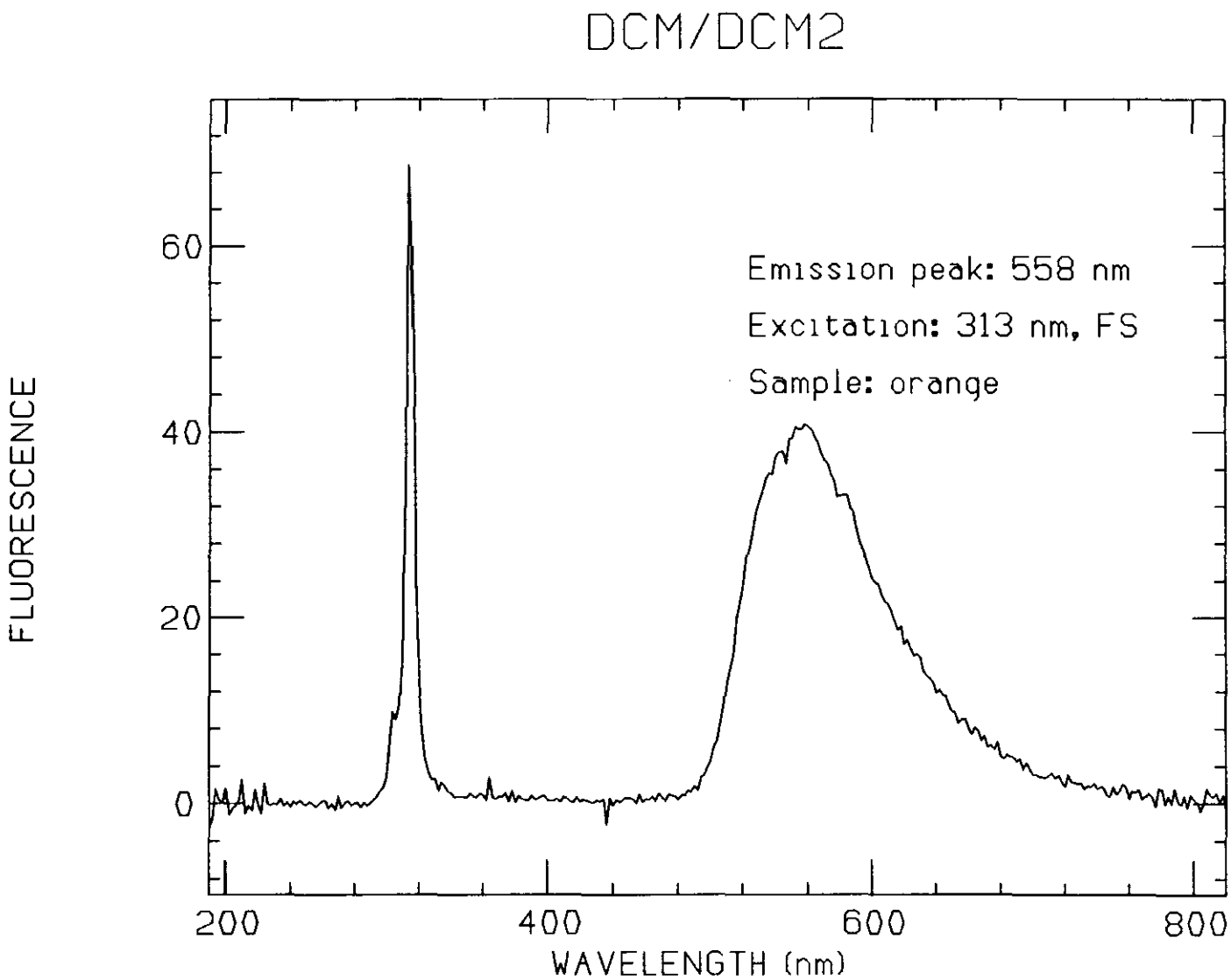

DASBTI
FLUORESCENCE
100
75
50
25
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 474 nm
Excitation: 313 nm, FS
Sample: lt.greenish yellow

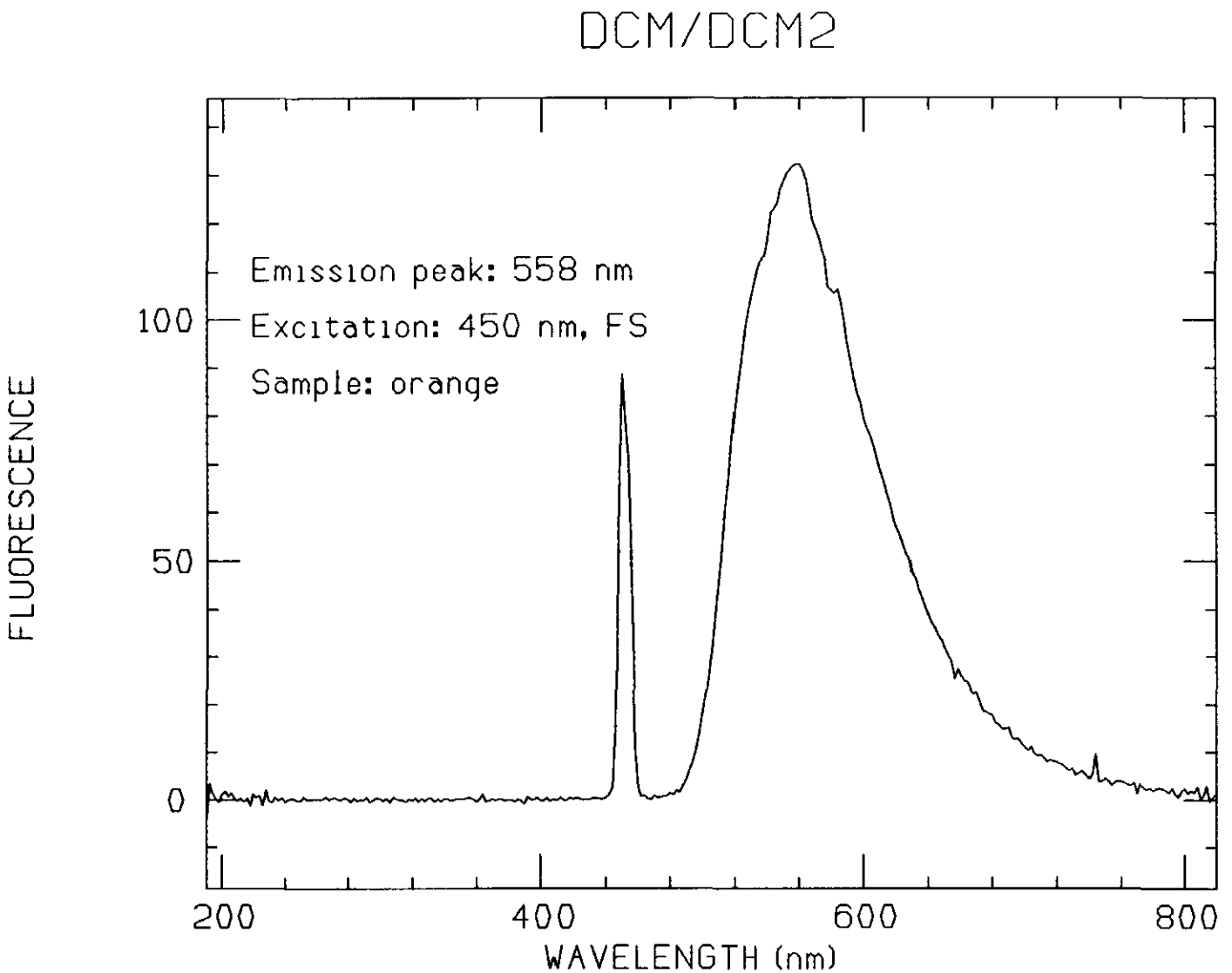

DASBTI
Emission peak: 474 nm
Excitation: 400 nm, FS
Sample: lt.greenish yellow
FLUORESCENCE
400
200
0
200
400
600
800
WAVELENGTH (nm)

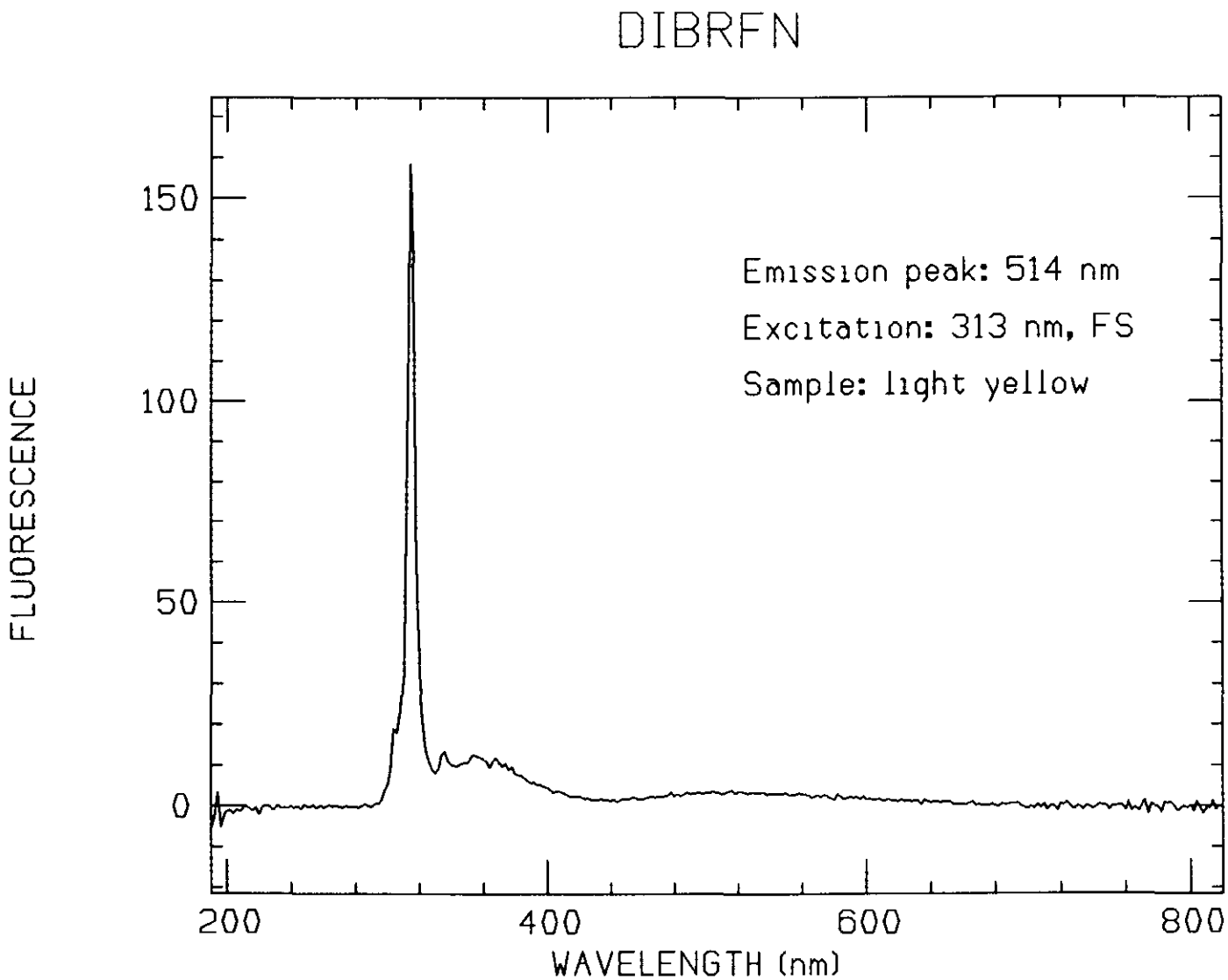

DASPI
FLUORESCENCE
150
100
50
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 440 nm
Excitation: 313 nm, FS
Sample: light yellow

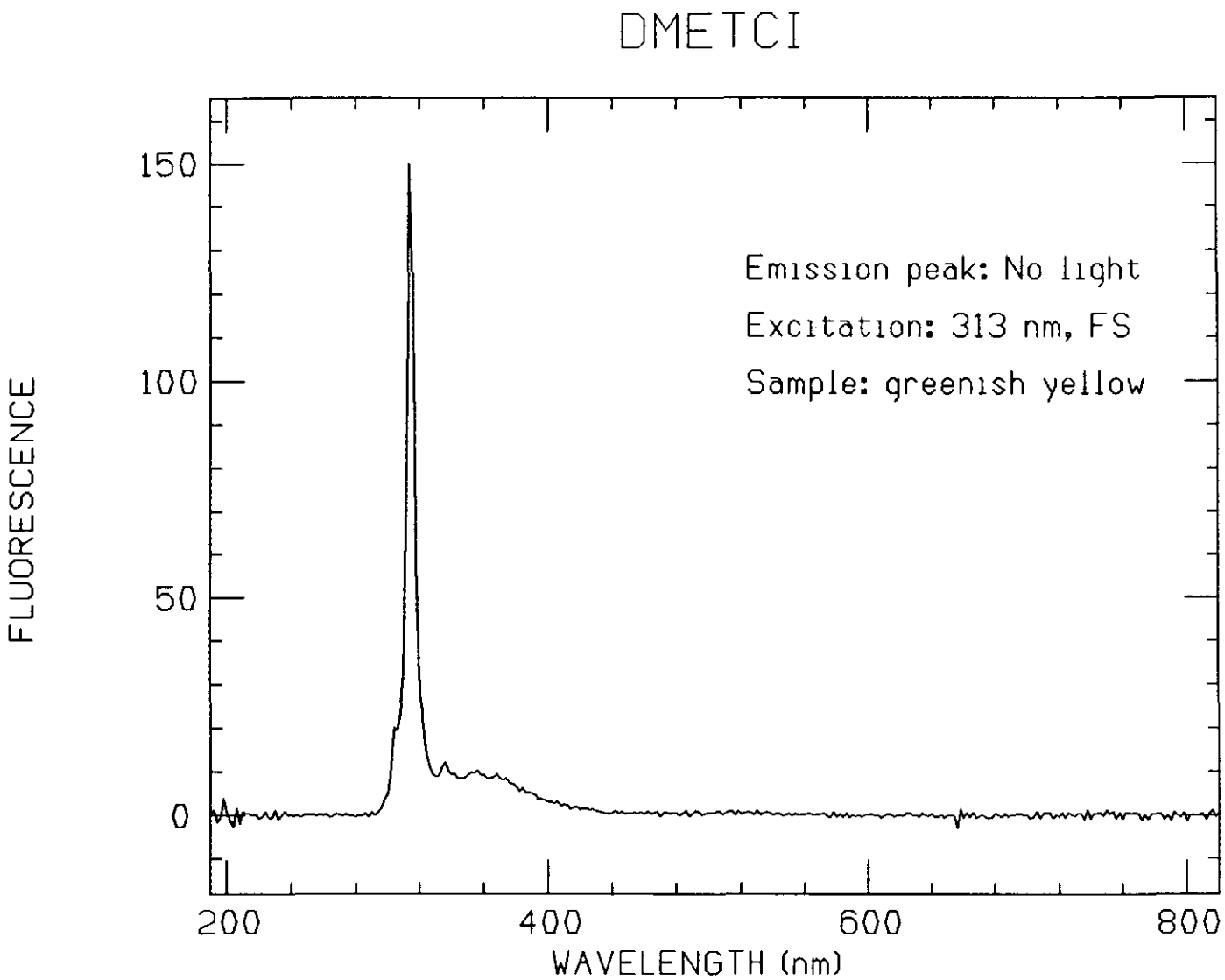

DASPI
FLUORESCENCE
400
300
200
100
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 440 nm
Excitation: 360 nm, FS
Sample: light yellow

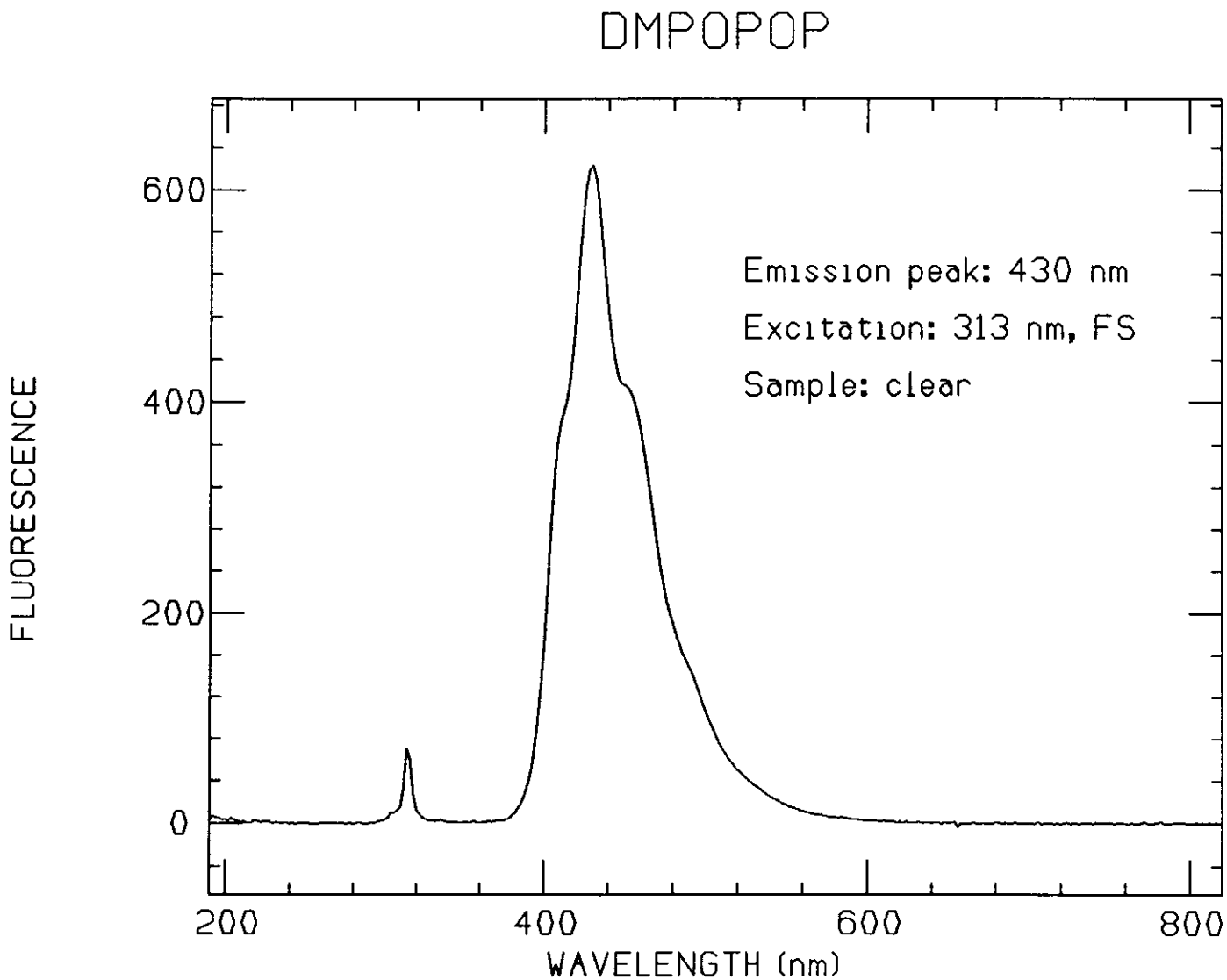

DCI2
150
100
50
0
FLUORESCENCE
Emission peak: 474 nm
Excitation: 313 nm, FS
Sample: olive
200
400
600
800
WAVELENGTH (nm)

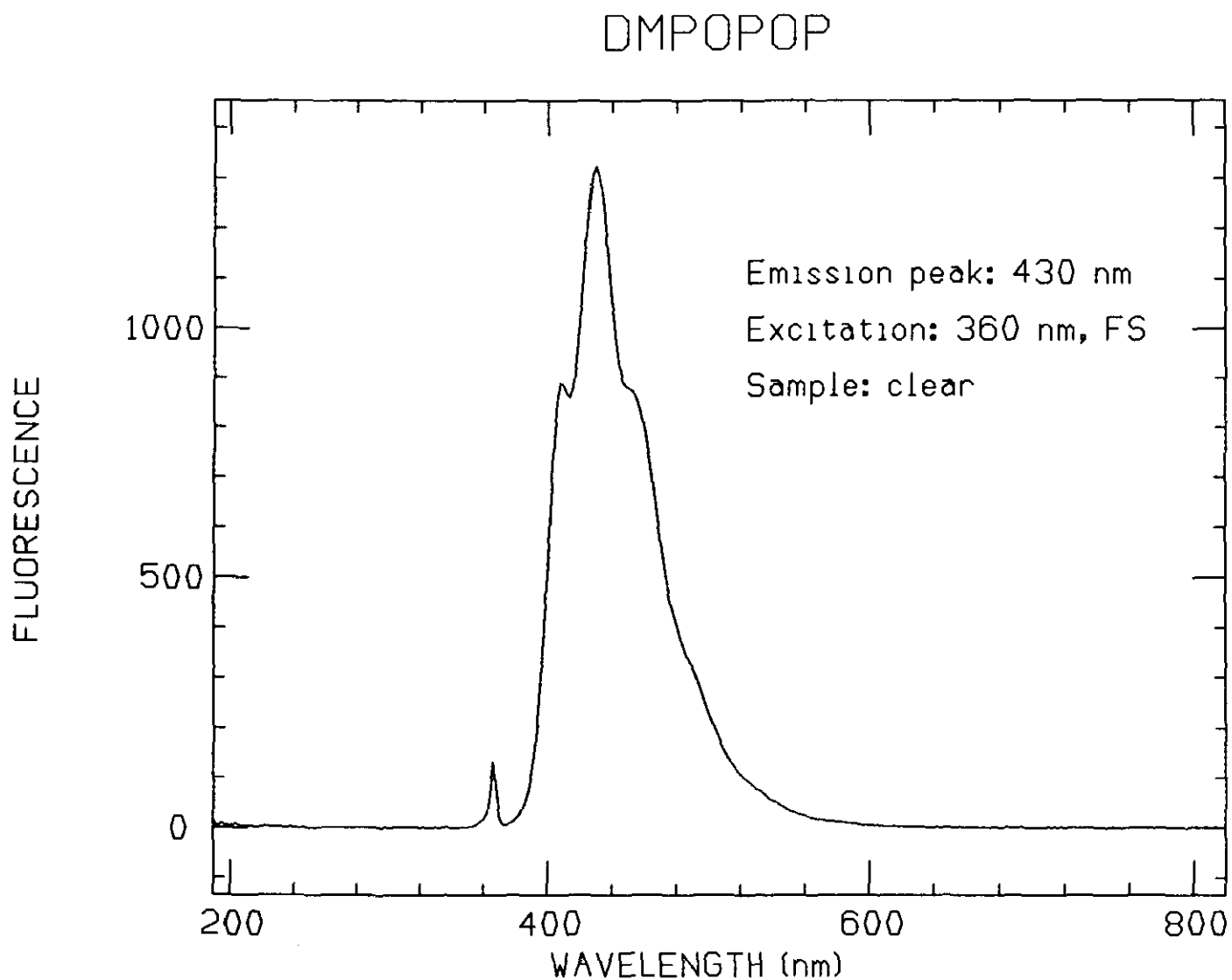

DCM/DCM2
FLUORESCENCE
60
40
20
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 558 nm
Excitation: 313 nm, FS
Sample: orange

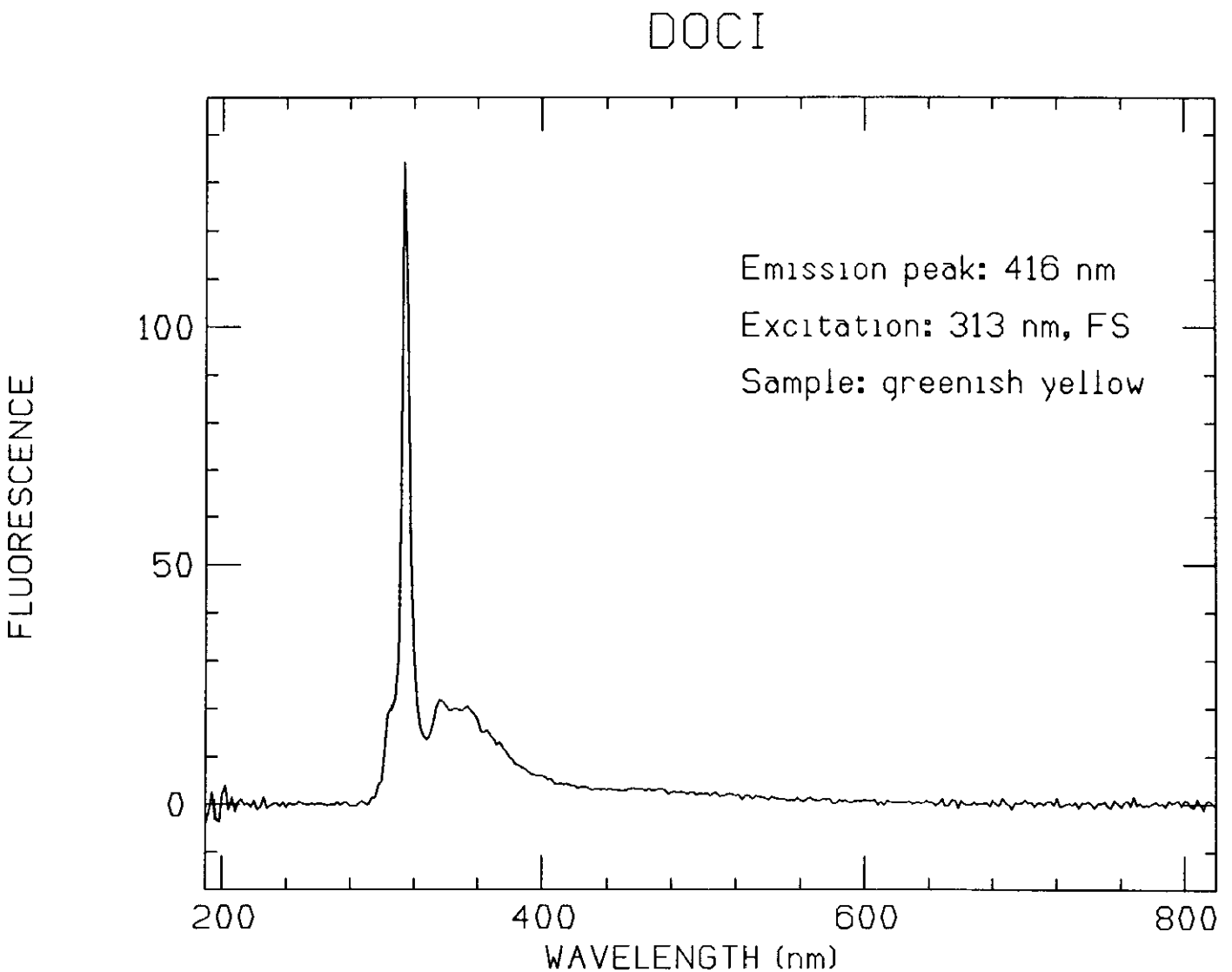

DCM/DCM2
Emission peak: 558 nm
Excitation: 450 nm, FS
Sample: orange
FLUORESCENCE
100
50
0
200
400
600
800
WAVELENGTH (nm)

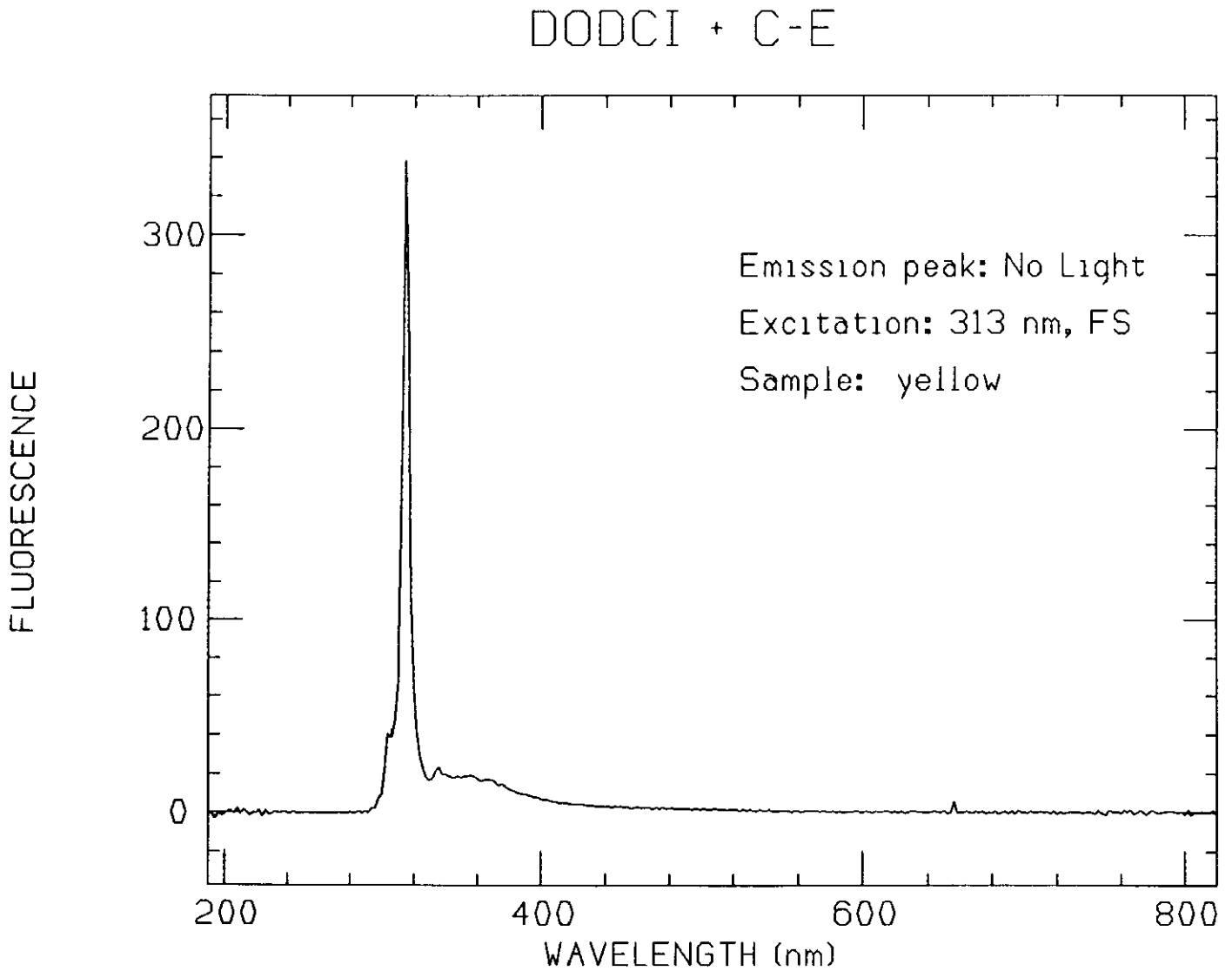

DIBRFN
FLUORESCENCE
150
100
50
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 514 nm
Excitation: 313 nm, FS
Sample: light yellow

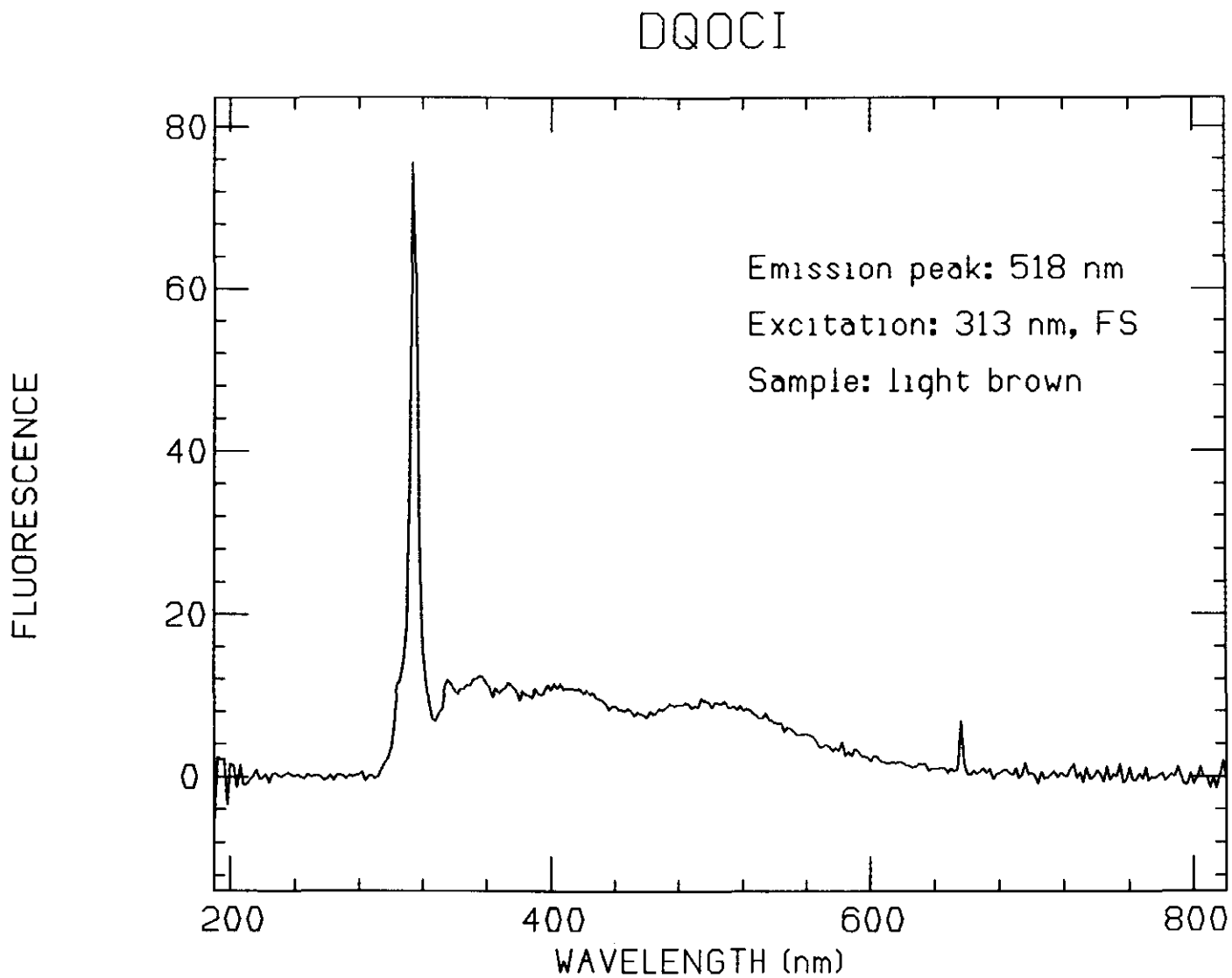

DMETCI
FLUORESCENCE
150
100
50
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: No light
Excitation: 313 nm, FS
Sample: greenish yellow

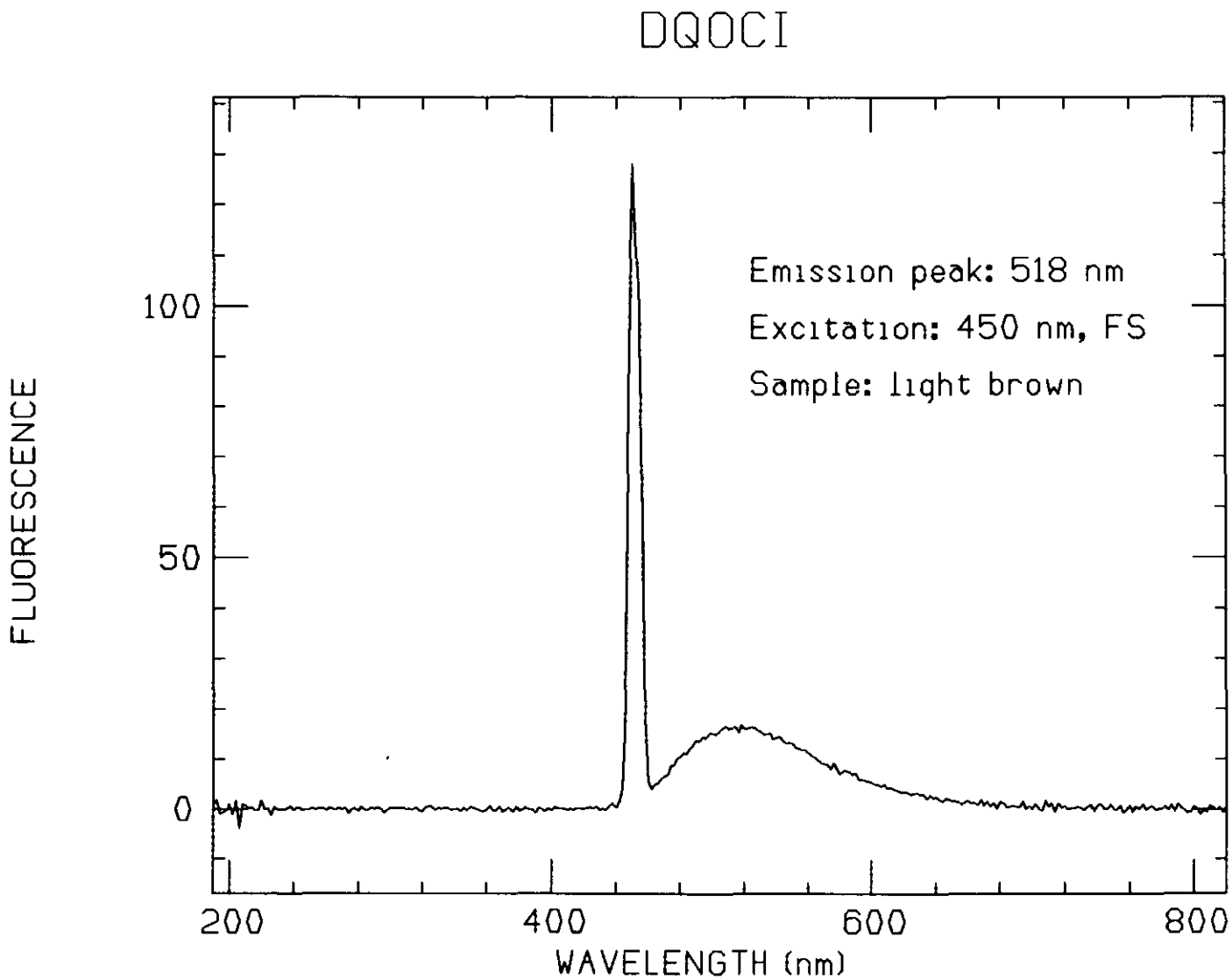

DMPOPOP
FLUORESCENCE
600
400
200
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 430 nm
Excitation: 313 nm, FS
Sample: clear

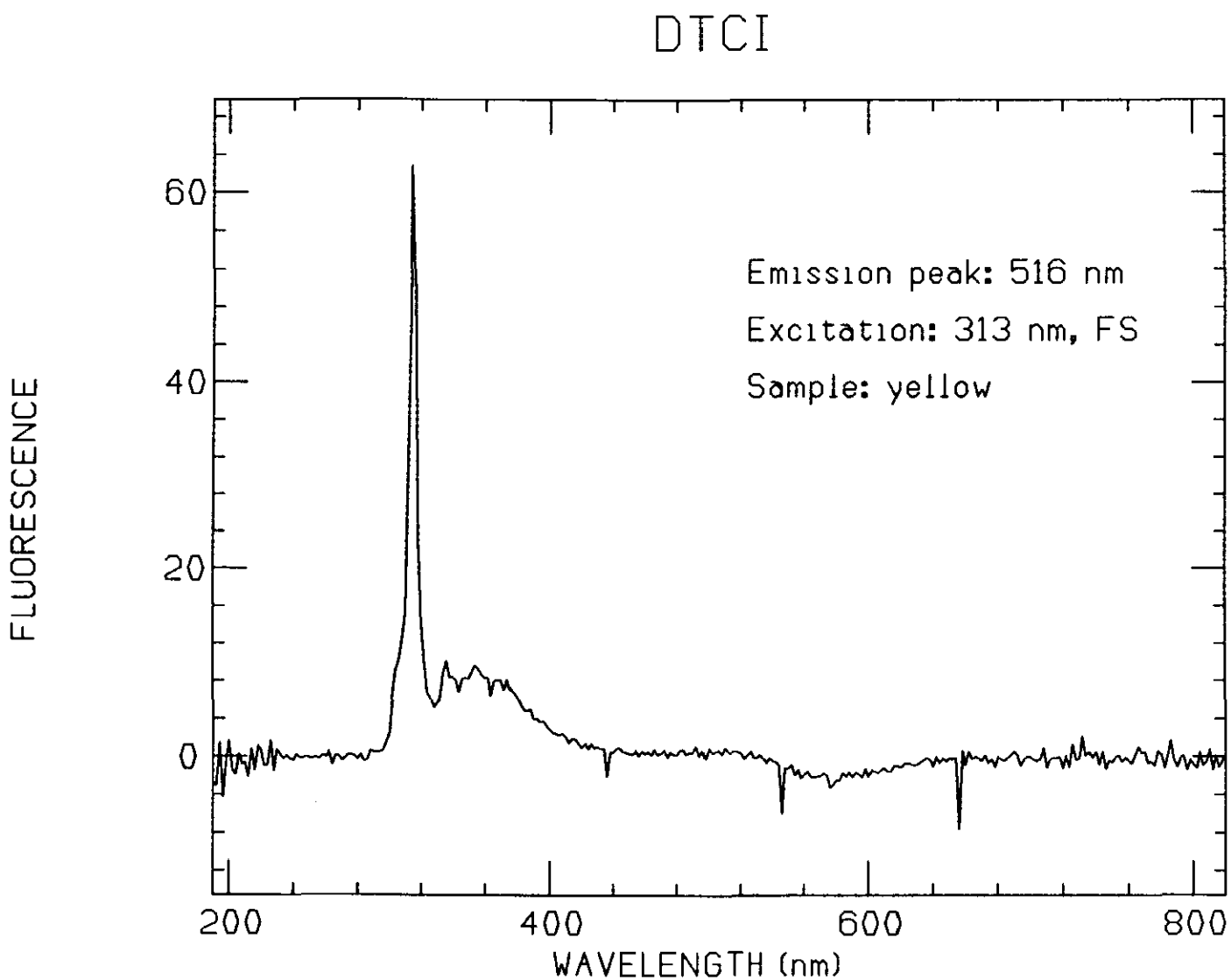

DMPOPOP
Emission peak: 430 nm
Excitation: 360 nm, FS
Sample: clear
FLUORESCENCE
1000
500
0
200
400
600
800
WAVELENGTH (nm)

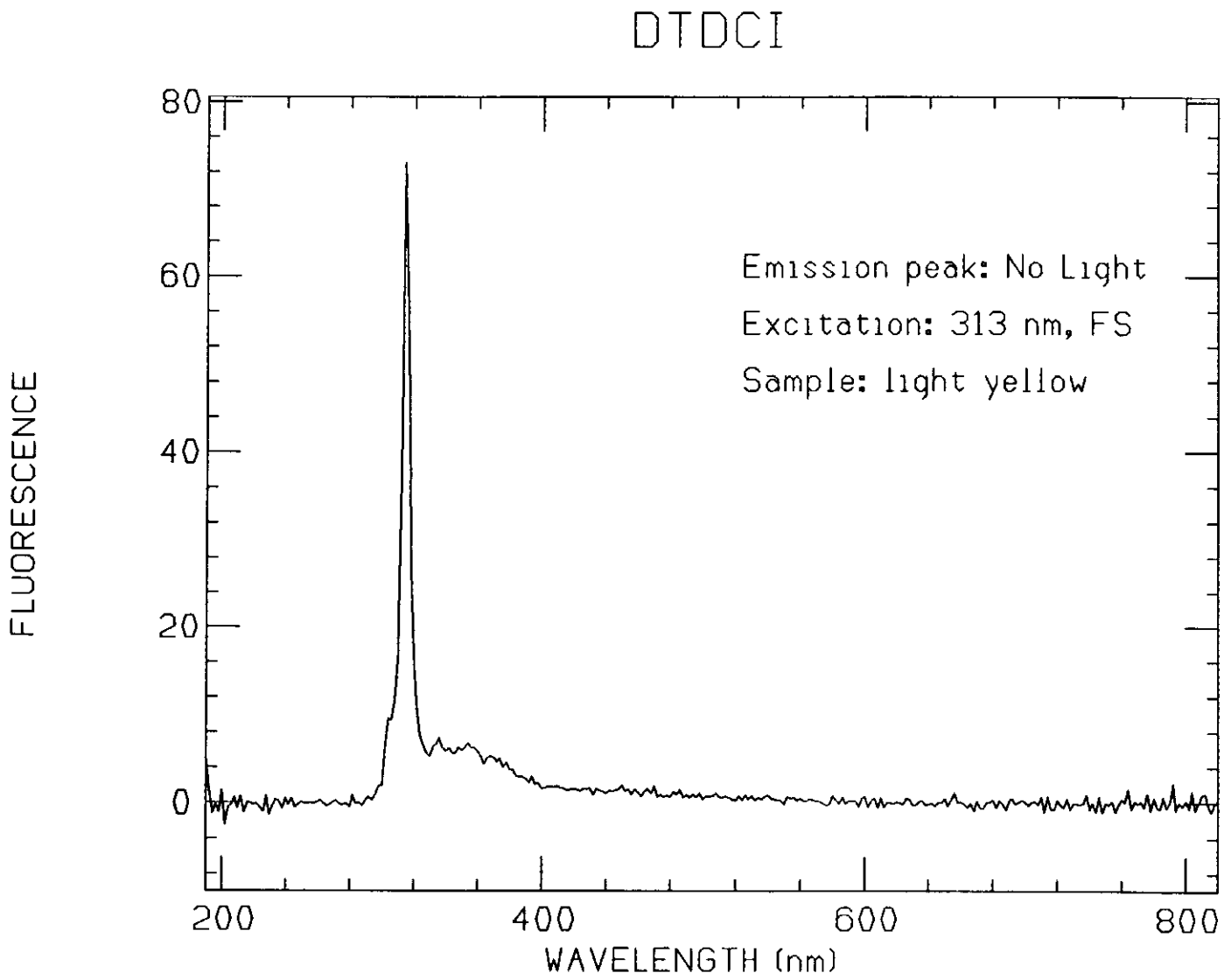

DOCI
Emission peak: 416 nm
Excitation: 313 nm, FS
Sample: greenish yellow
FLUORESCENCE
100
50
0
200
400
600
800
WAVELENGTH (nm)

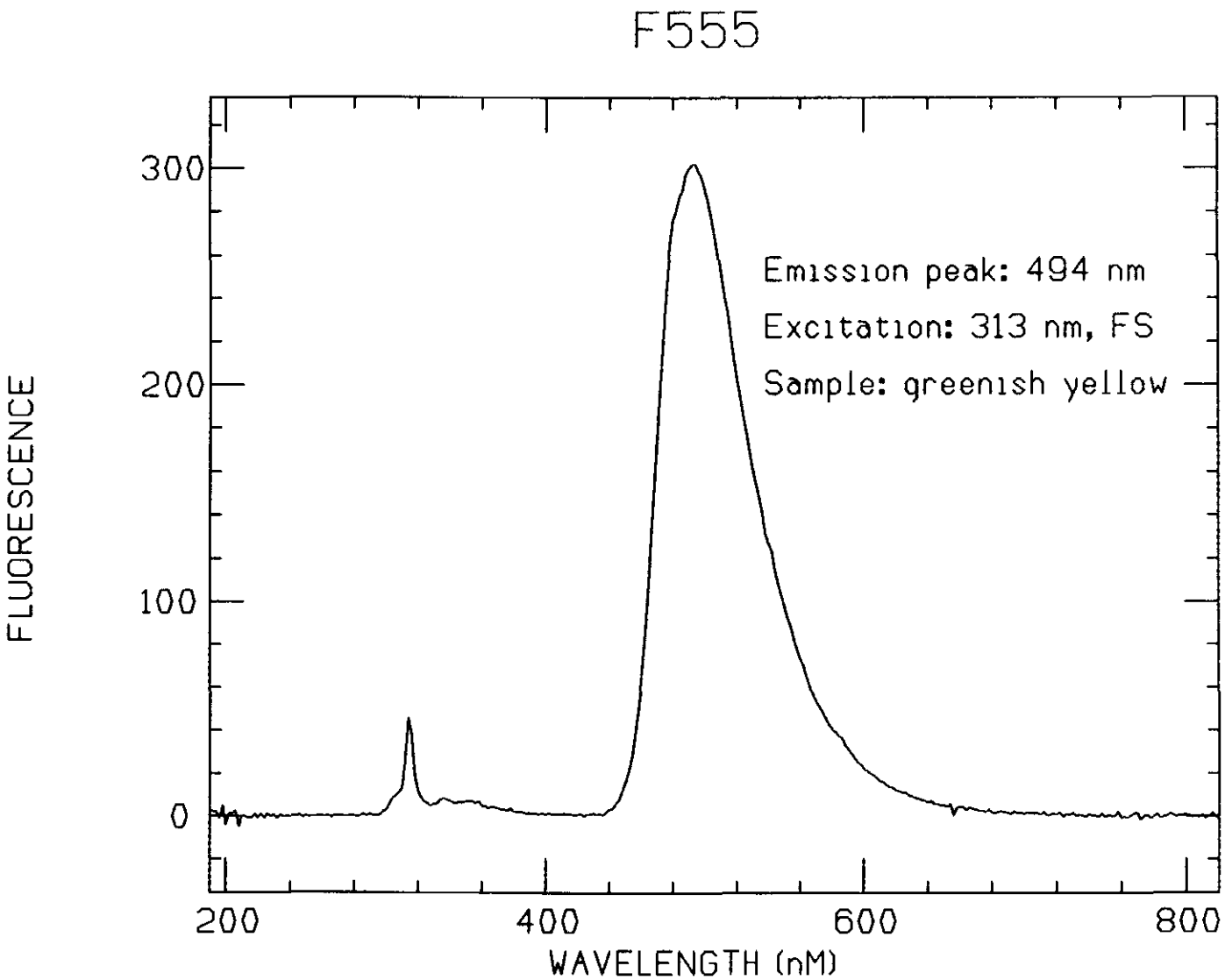

DODCI + C-E
FLUORESCENCE
300
200
100
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: No Light
Excitation: 313 nm, FS
Sample: yellow

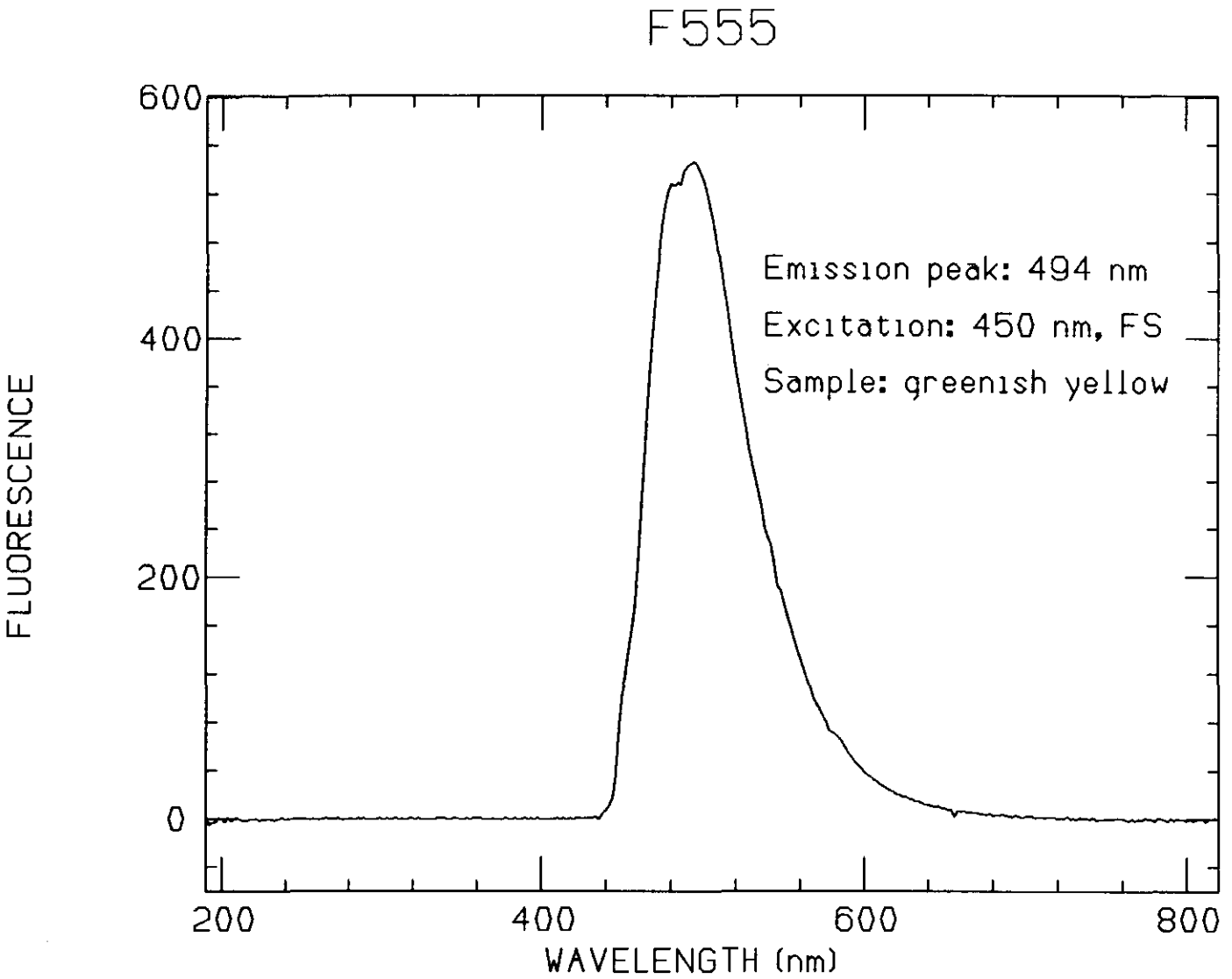

DQOCI
FLUORESCENCE
80
60
40
20
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 518 nm
Excitation: 313 nm, FS
Sample: light brown

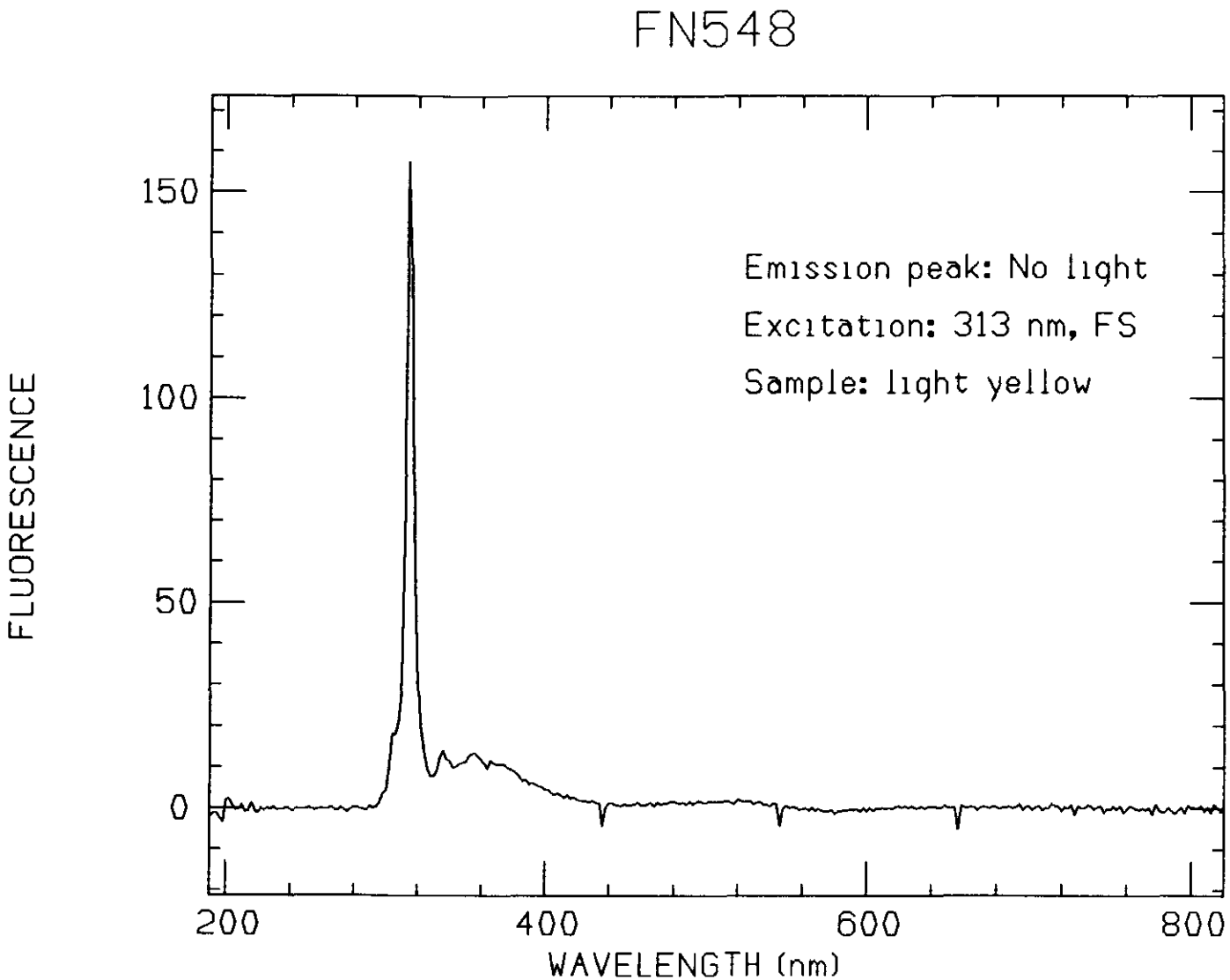

DQOCI
Emission peak: 518 nm
Excitation: 450 nm, FS
Sample: light brown
FLUORESCENCE
100
50
0
200
400
600
800
WAVELENGTH (nm)


DTCI
FLUORESCENCE
60
40
20
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 516 nm
Excitation: 313 nm, FS
Sample: yellow

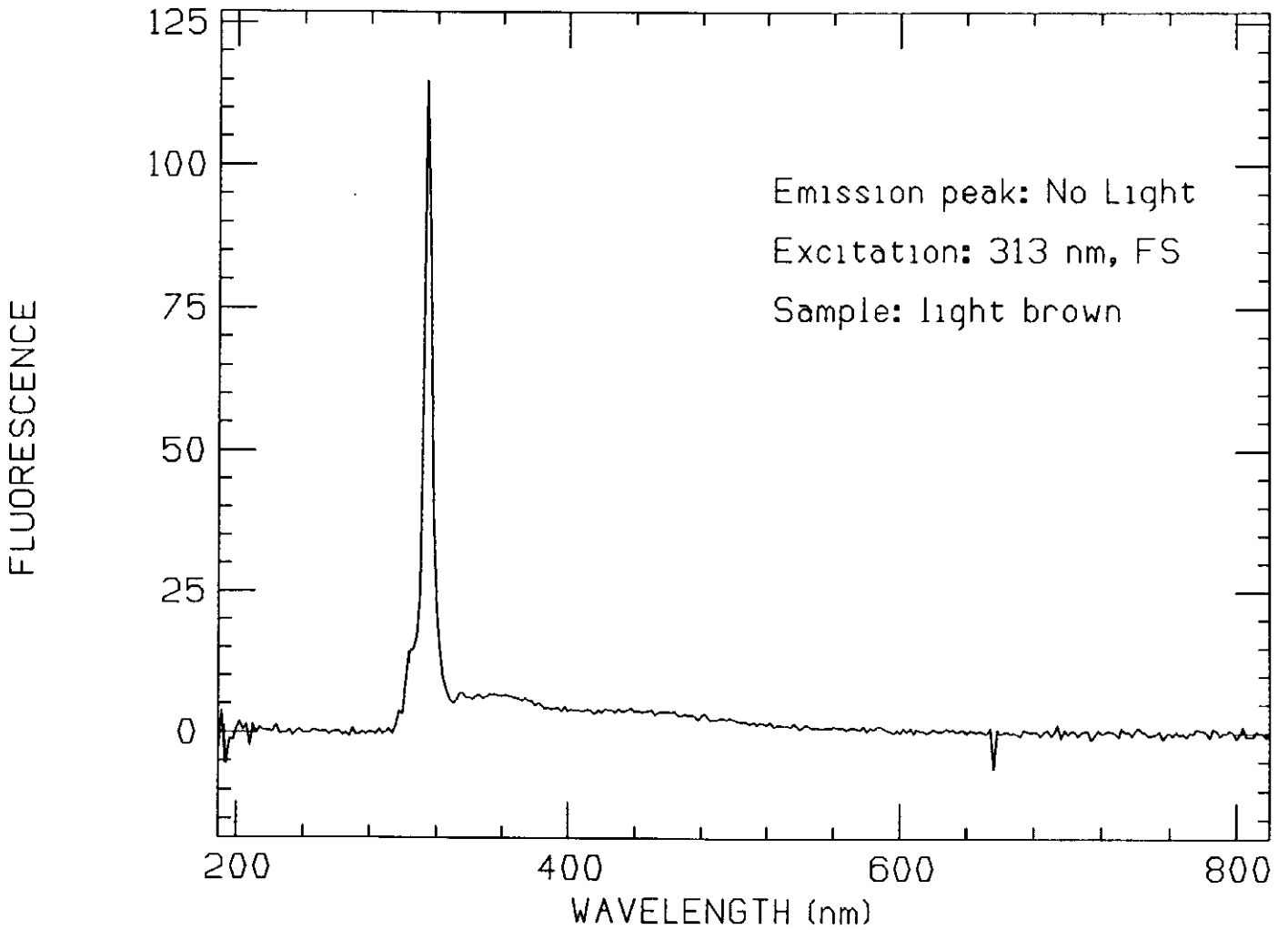

DTDCI
FLUORESCENCE
80
60
40
20
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: No Light
Excitation: 313 nm, FS
Sample: light yellow

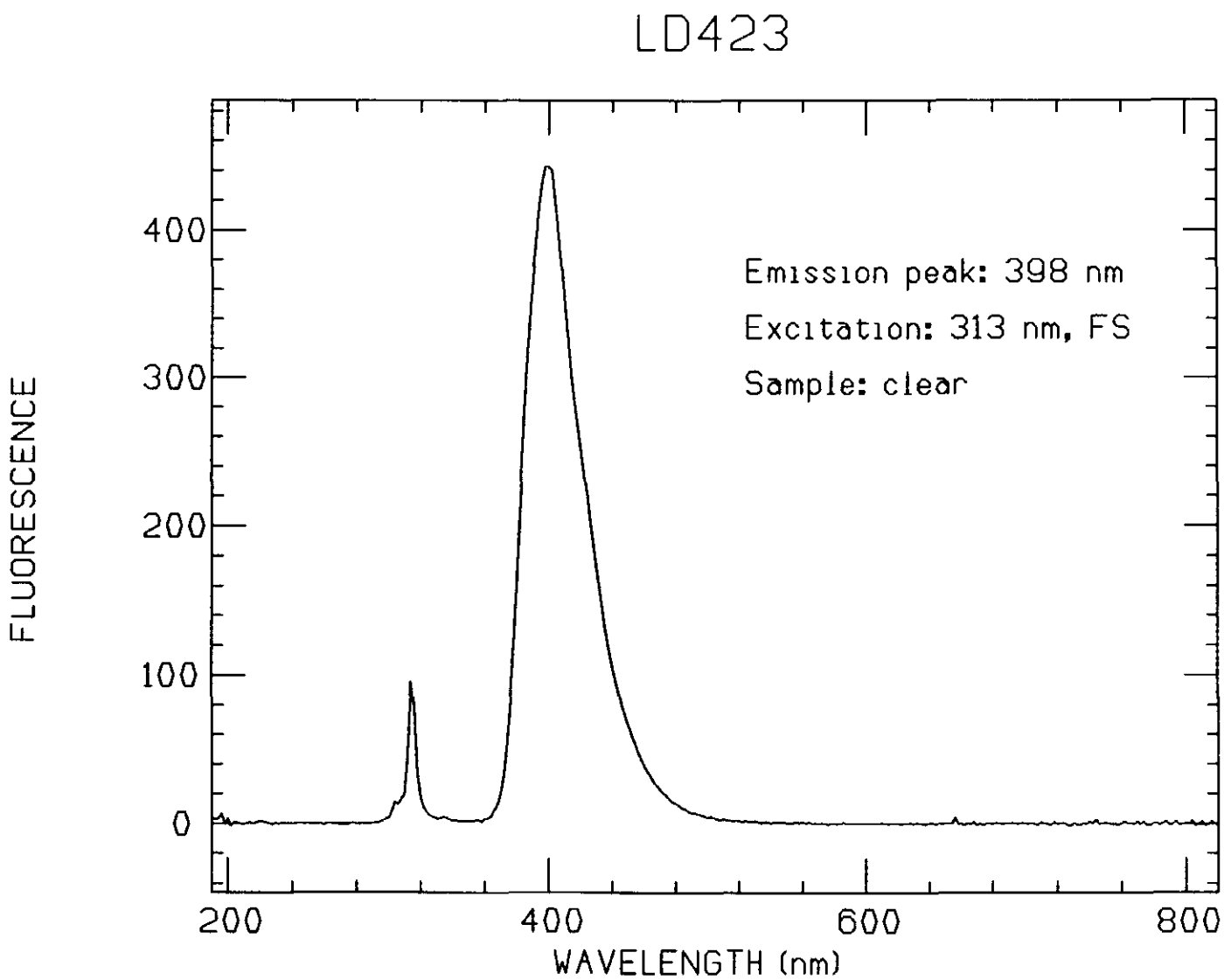

F555
FLUORESCENCE
300
200
100
0
200
400
600
800
WAVELENGTH (nM)
Emission peak: 494 nm
Excitation: 313 nm, FS
Sample: greenish yellow

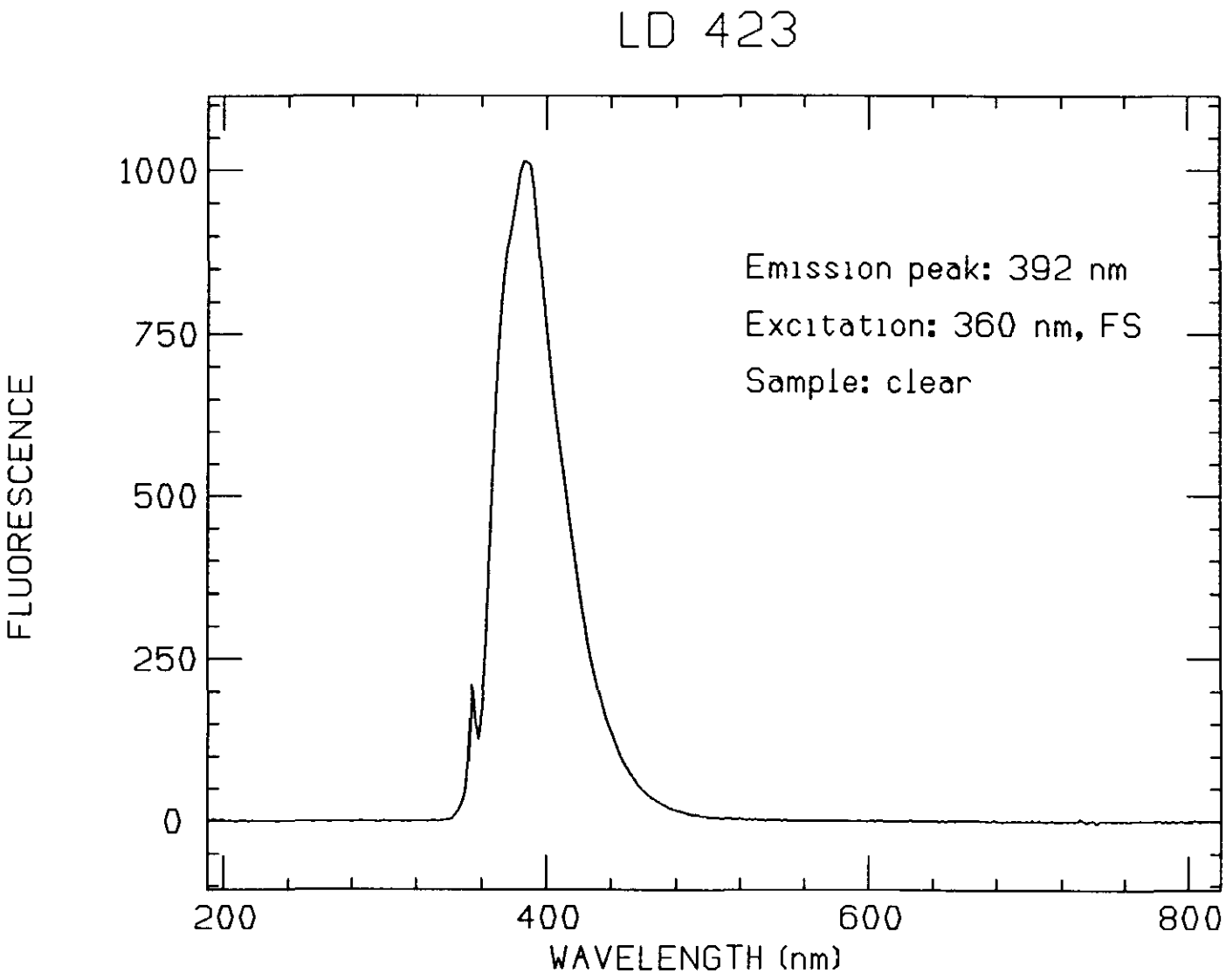

F555
600
400
200
0
FLUORESCENCE
Emission peak: 494 nm
Excitation: 450 nm, FS
Sample: greenish yellow
200
400
600
800
WAVELENGTH (nm)

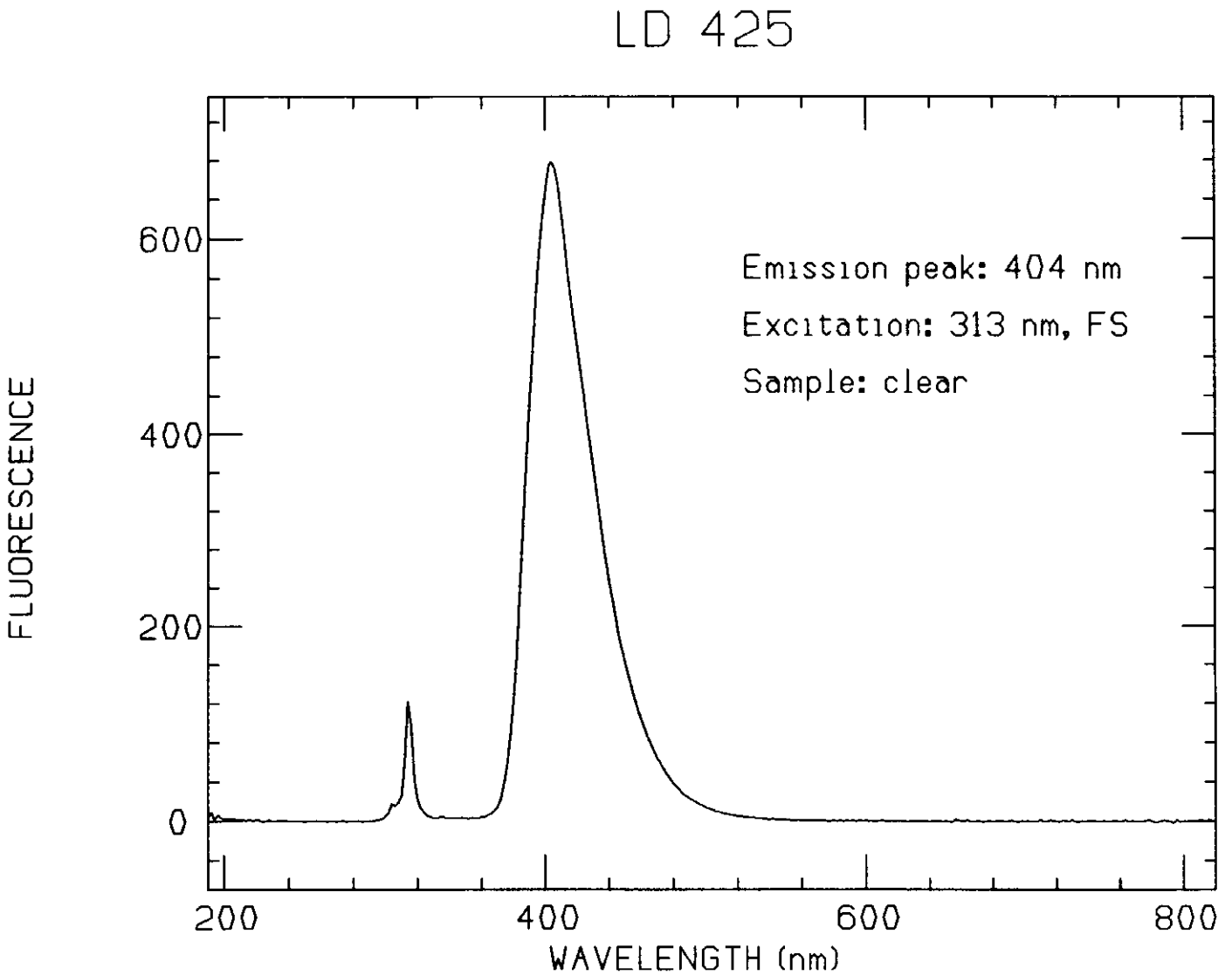

FN548
FLUORESCENCE
150
100
50
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: No light
Excitation: 313 nm, FS
Sample: light yellow

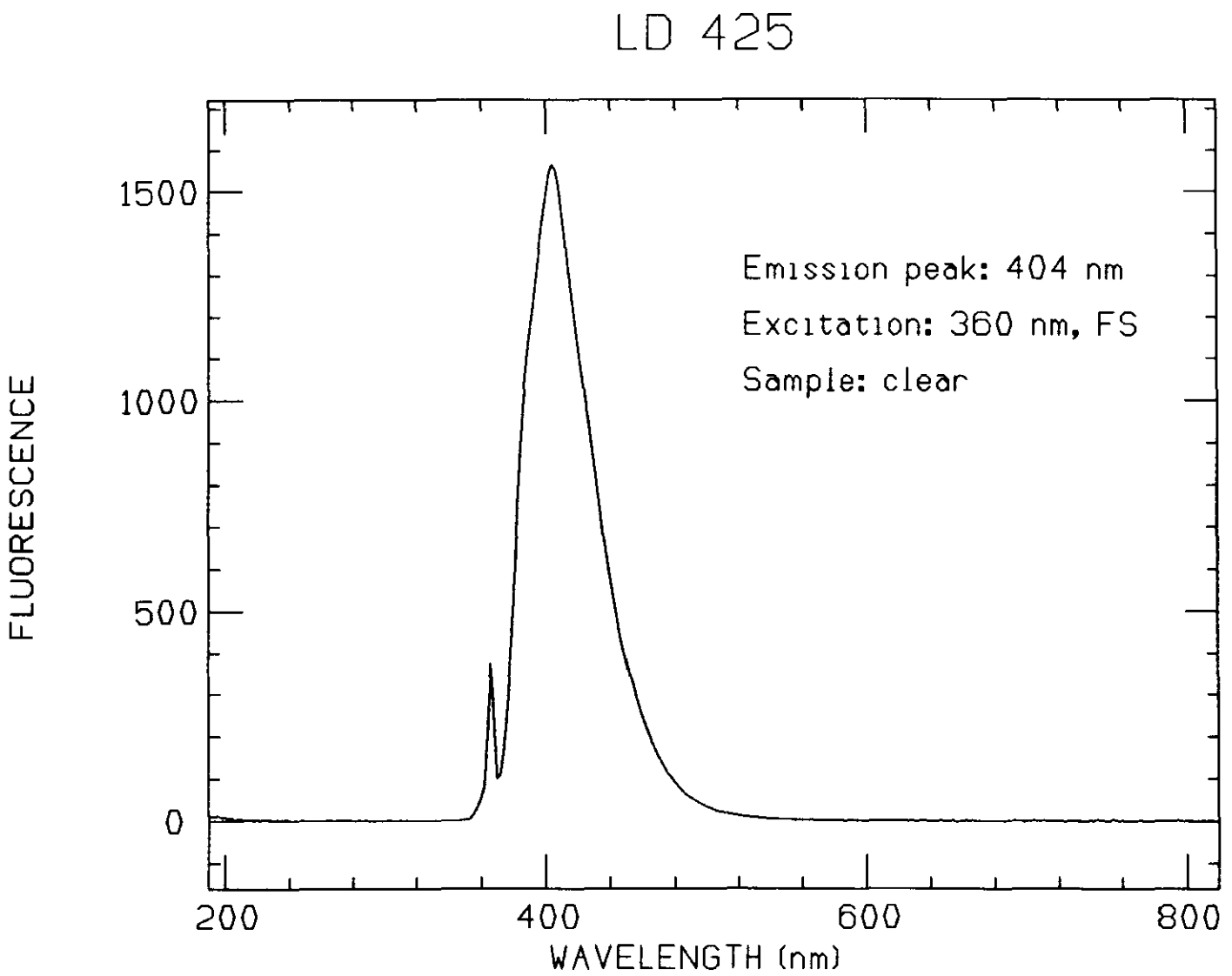
HIDC IODIDE + C-E

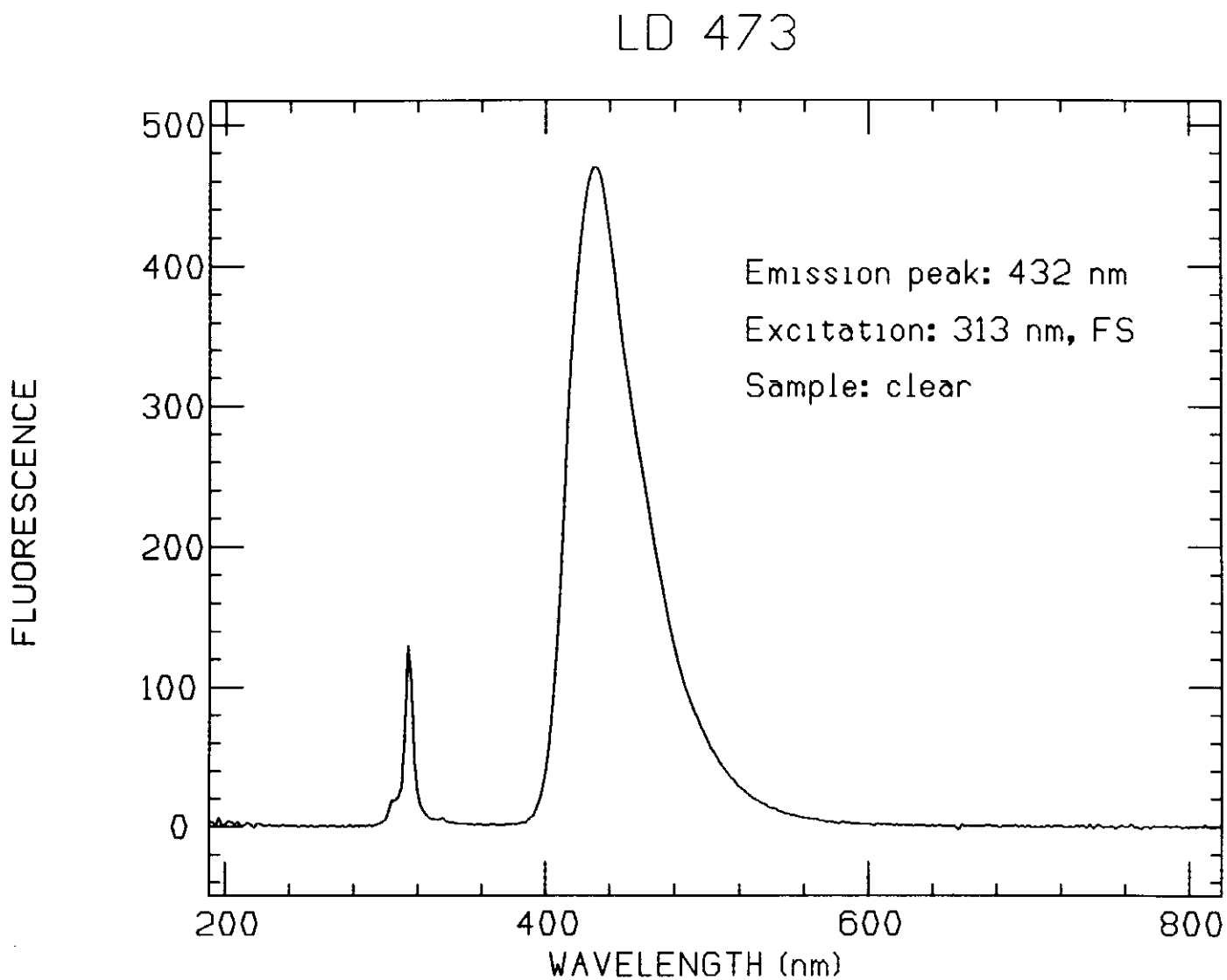


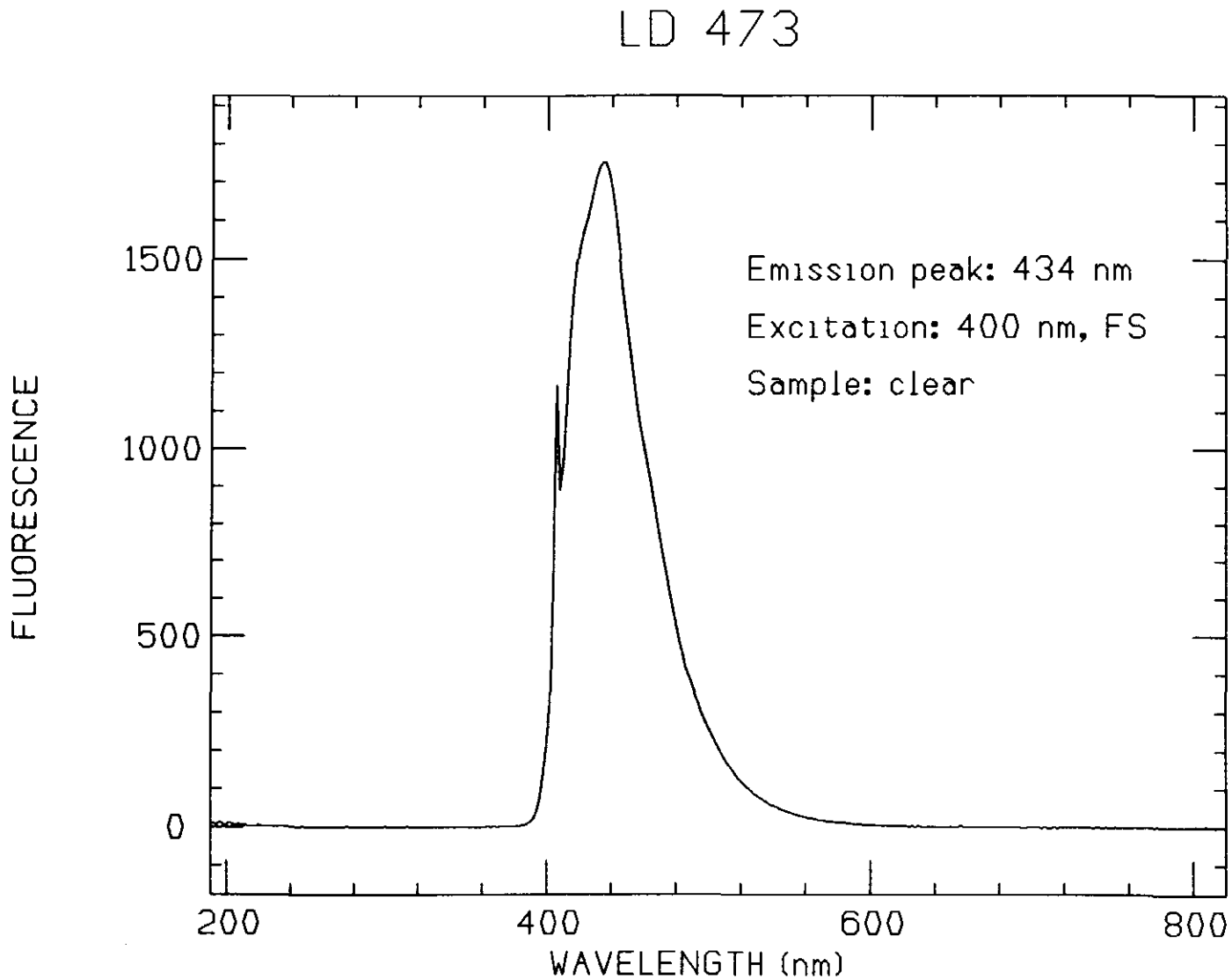

LD423
FLUORESCENCE
400
300
200
100
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 398 nm
Excitation: 313 nm, FS
Sample: clear

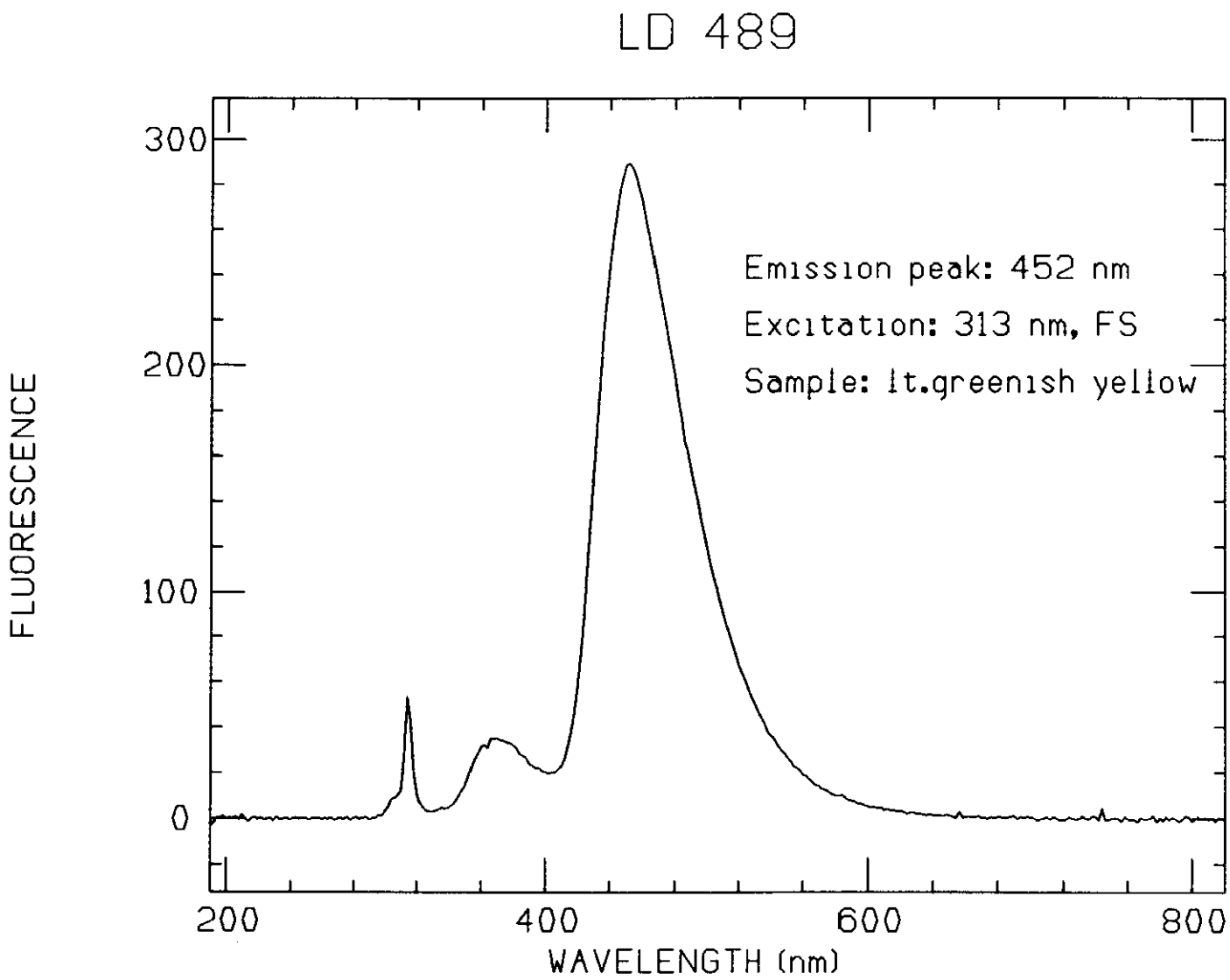

LD 423
FLUORESCENCE
1000
750
500
250
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 392 nm
Excitation: 360 nm, FS
Sample: clear

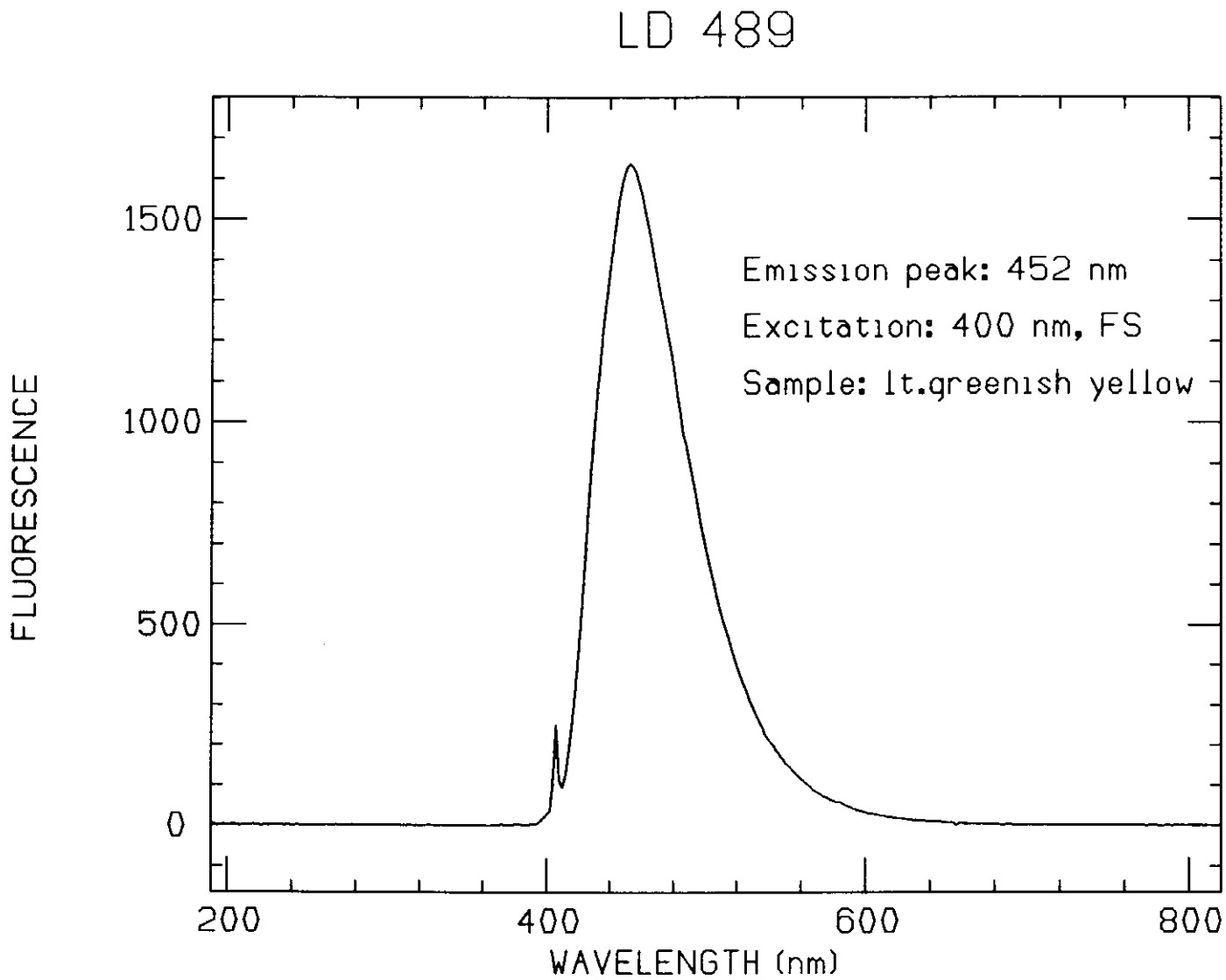

LD 425
FLUORESCENCE
600
400
200
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 404 nm
Excitation: 313 nm, FS
Sample: clear

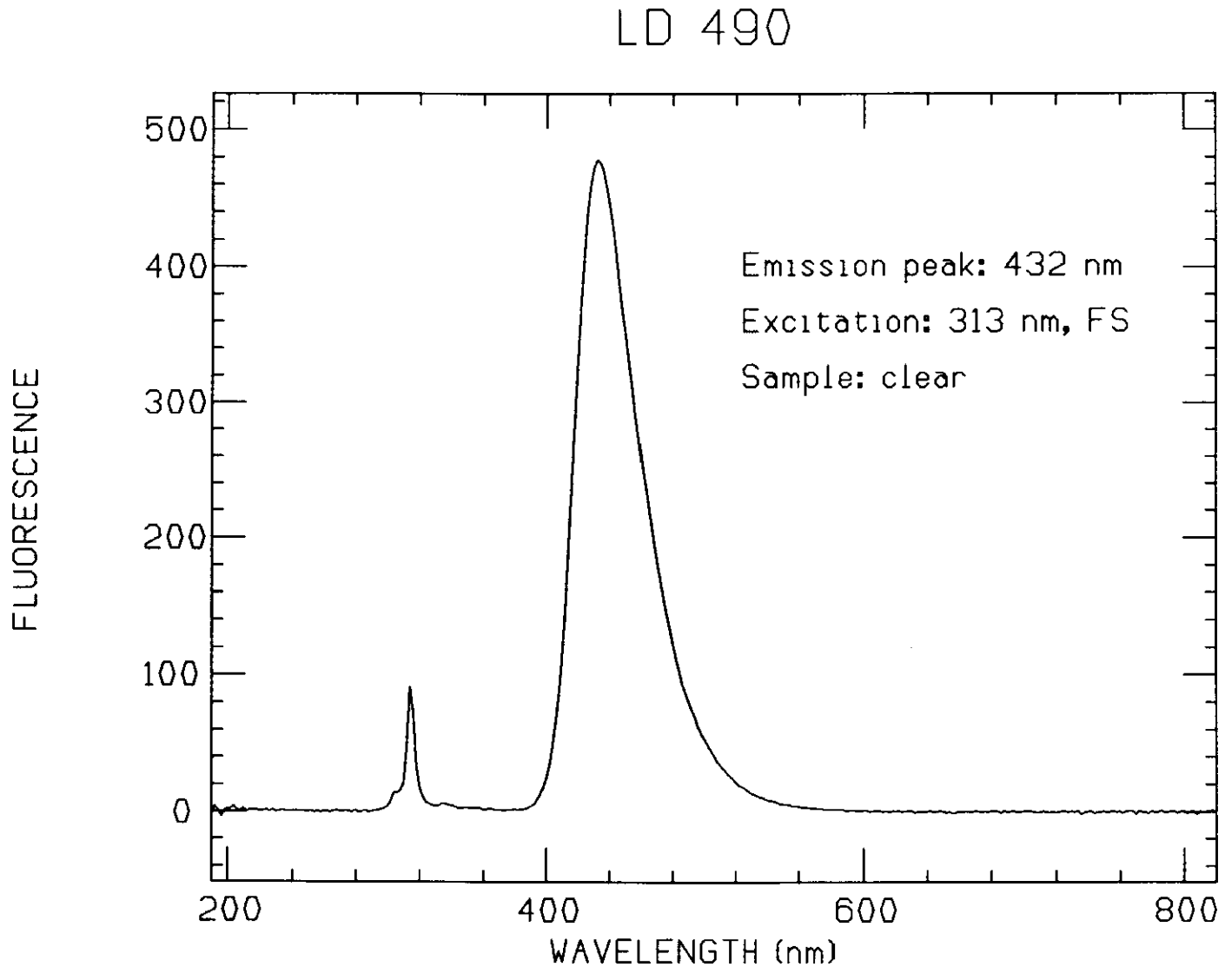

LD 425
FLUORESCENCE
1500
1000
500
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 404 nm
Excitation: 360 nm, FS
Sample: clear

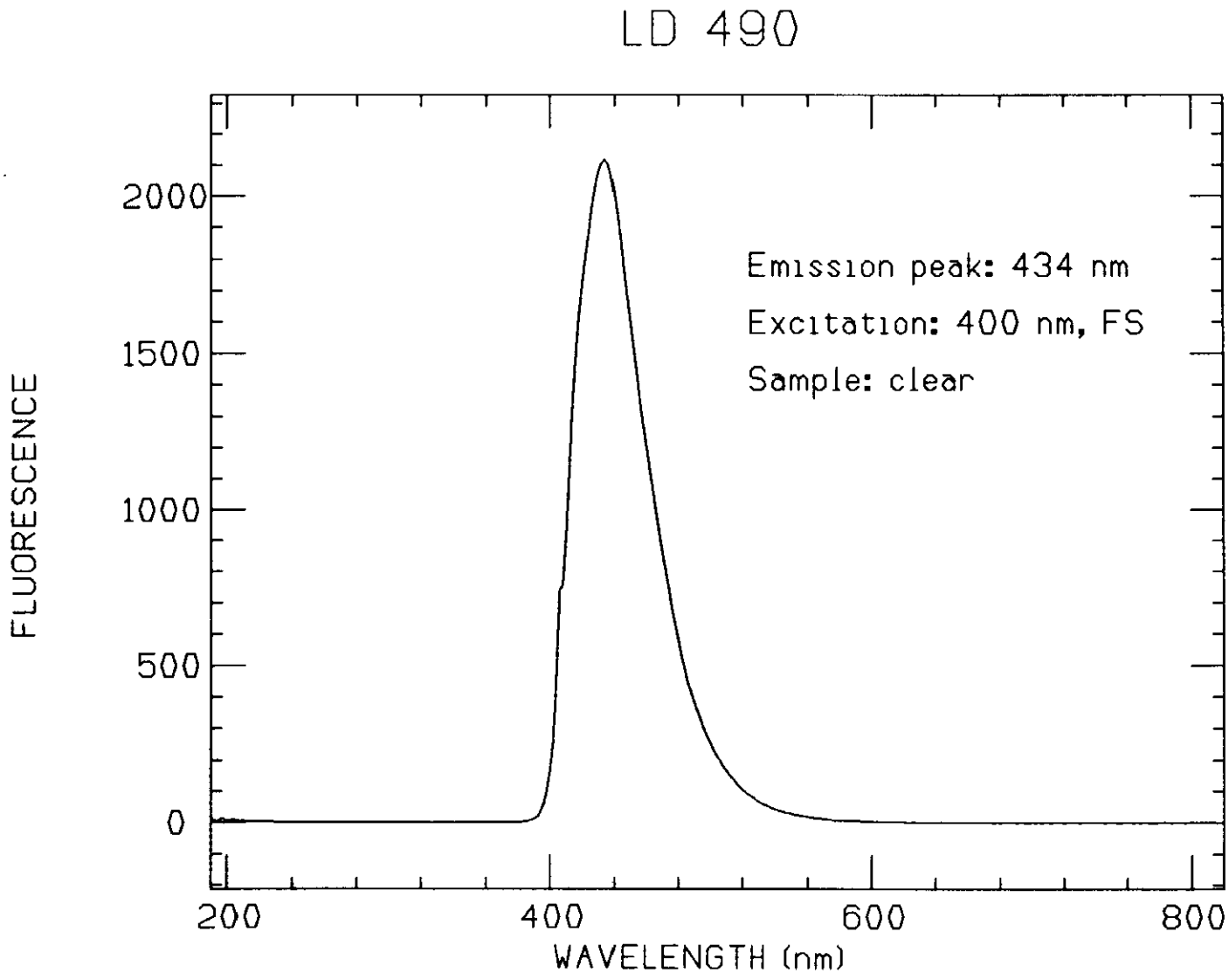

LD 473
FLUORESCENCE
500
400
300
200
100
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 432 nm
Excitation: 313 nm, FS
Sample: clear

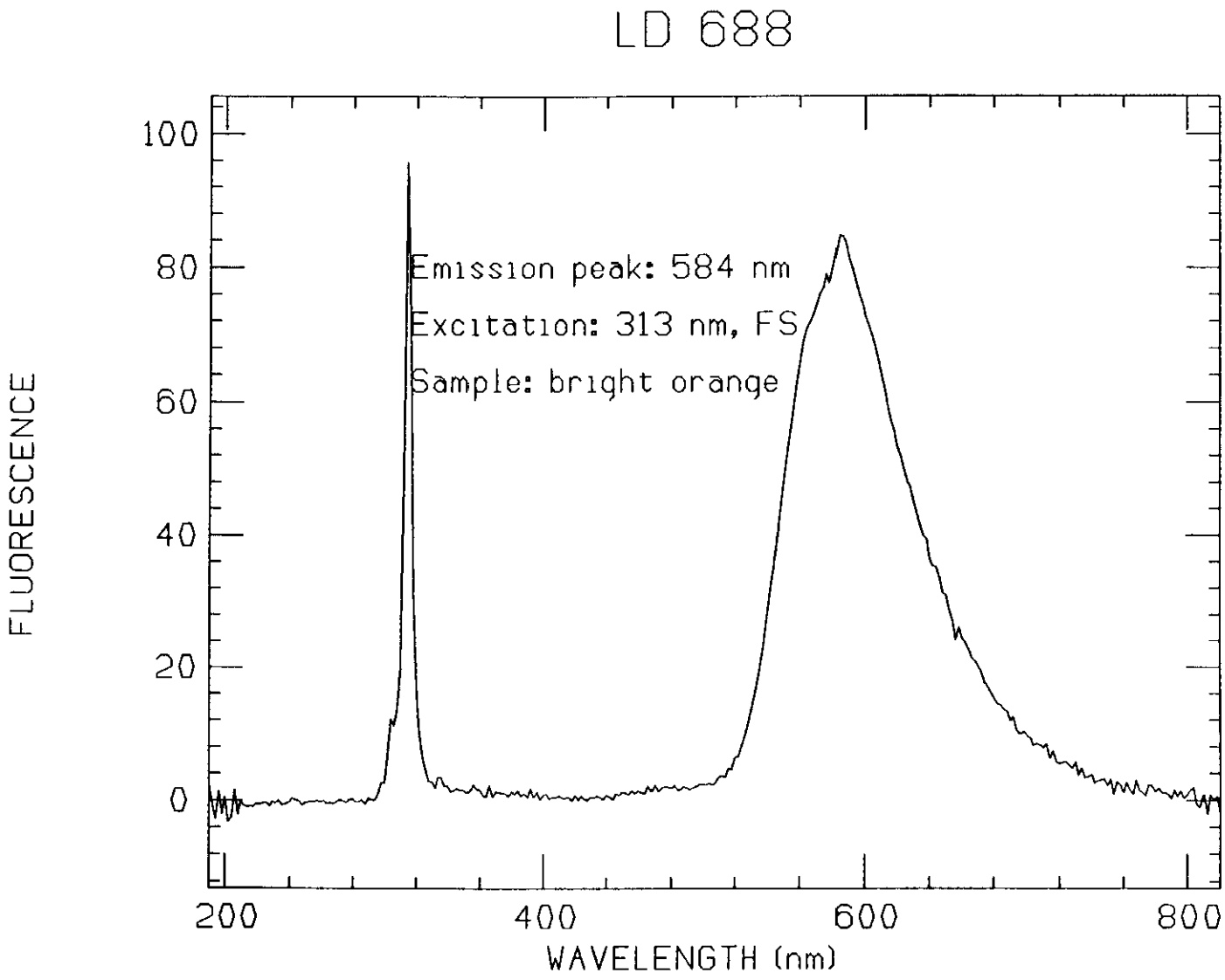

LD 473
FLUORESCENCE
1500
1000
500
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 434 nm
Excitation: 400 nm, FS
Sample: clear

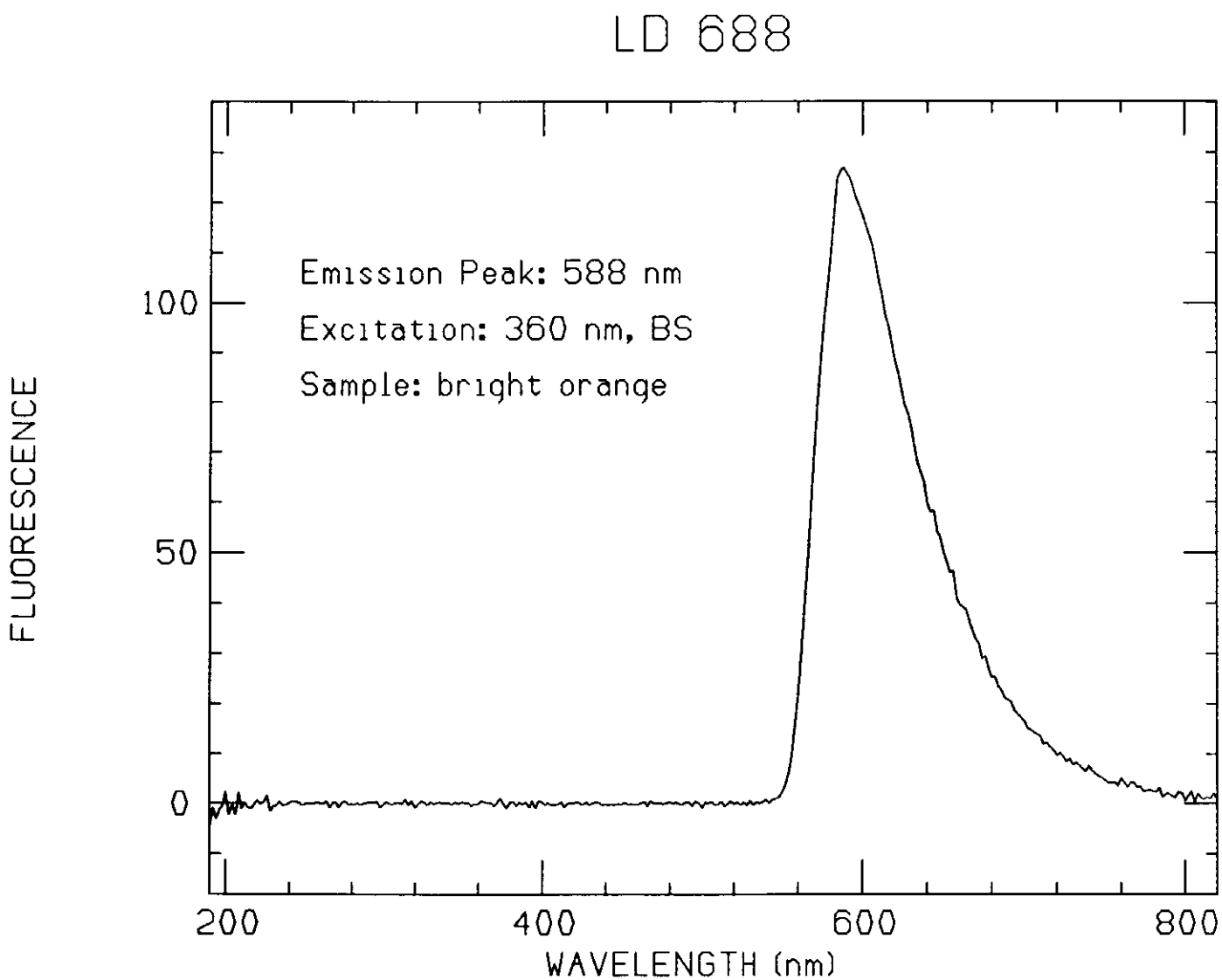

LD 489
FLUORESCENCE
300
200
100
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 452 nm
Excitation: 313 nm, FS
Sample: lt.greenish yellow

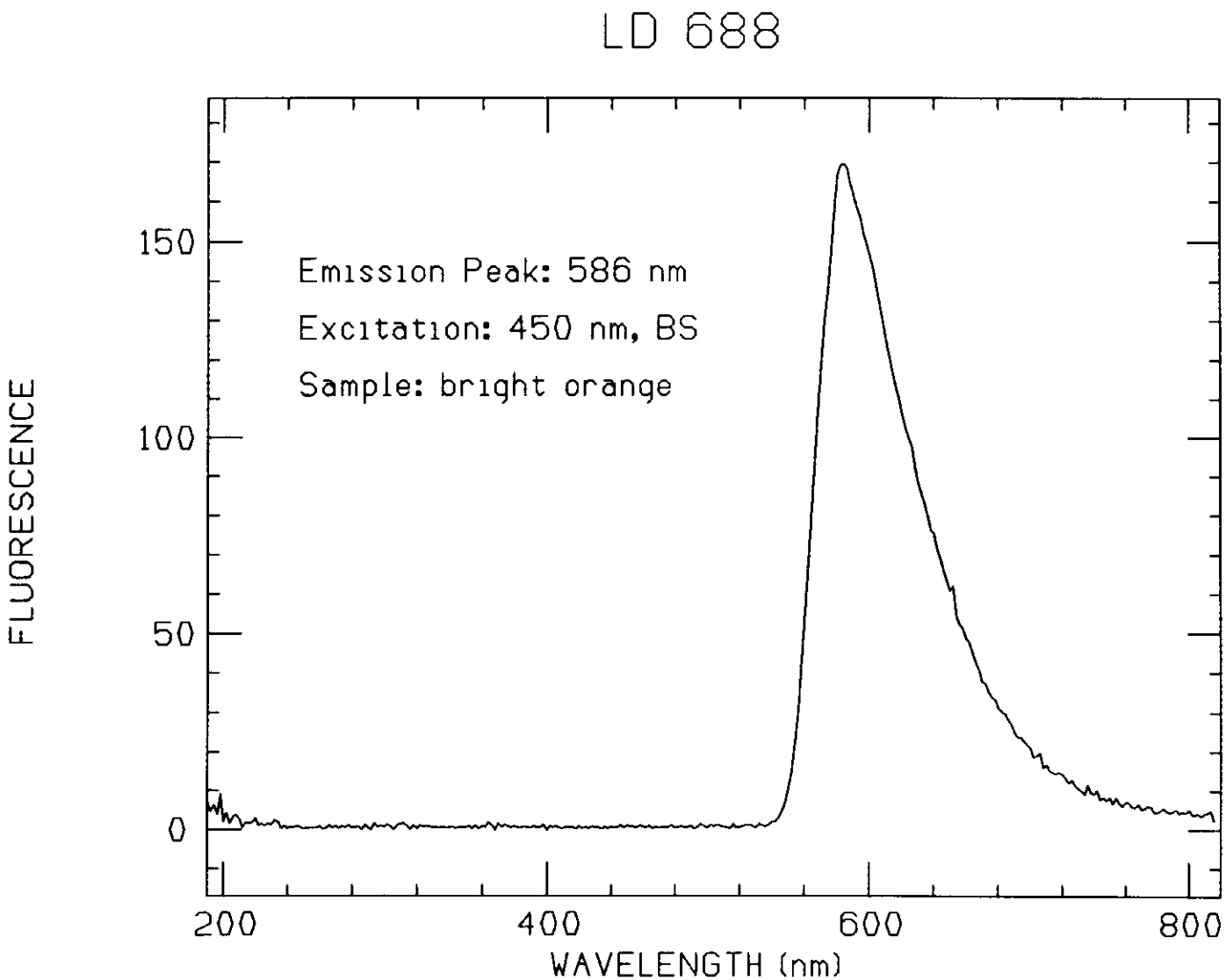

LD 489
FLUORESCENCE
1500
1000
500
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 452 nm
Excitation: 400 nm, FS
Sample: lt.greenish yellow

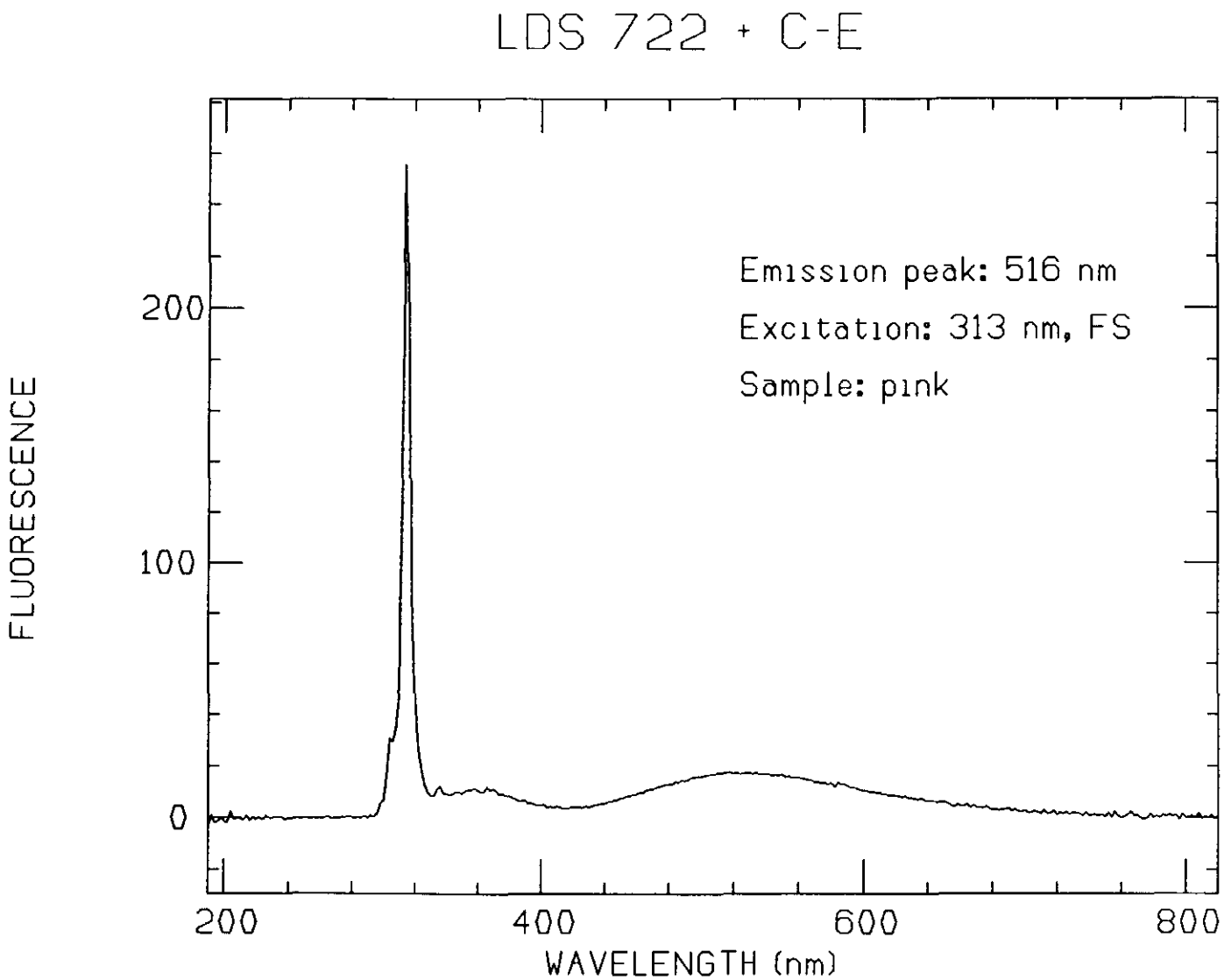

LD 490
FLUORESCENCE
500
400
300
200
100
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 432 nm
Excitation: 313 nm, FS
Sample: clear

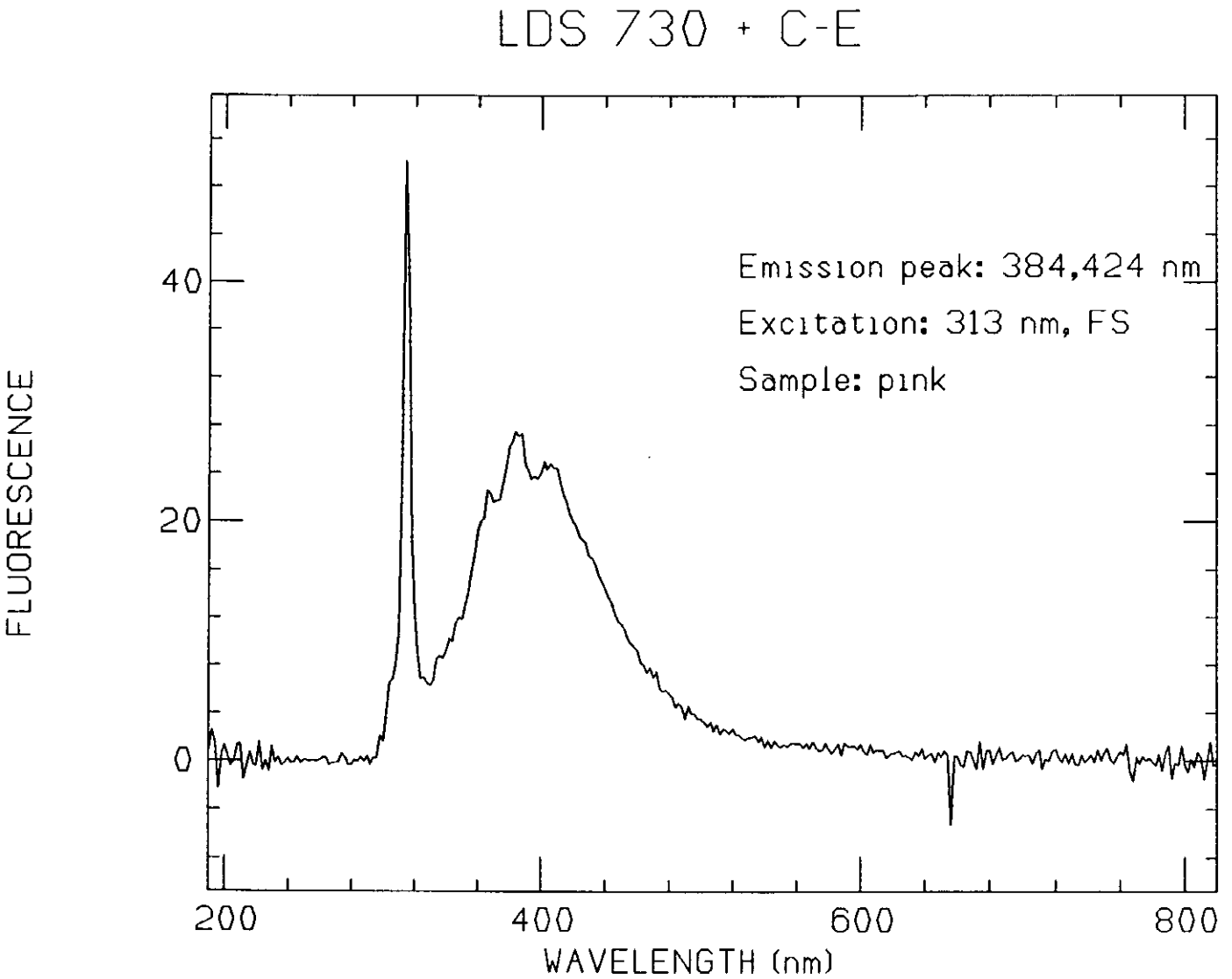

LD 490
FLUORESCENCE
2000
1500
1000
500
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 434 nm
Excitation: 400 nm, FS
Sample: clear

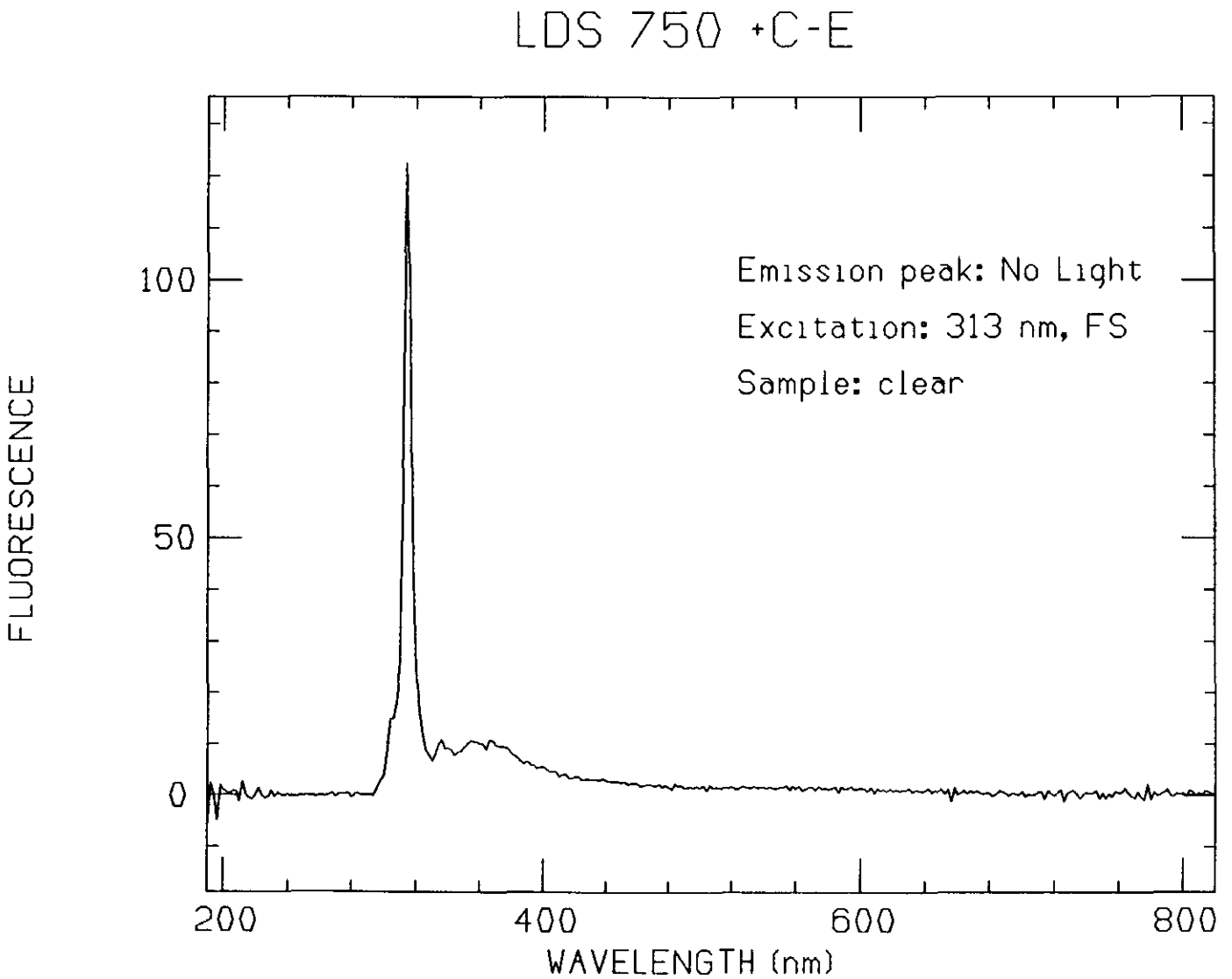

LD 688
FLUORESCENCE
100
80
60
40
20
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 584 nm
Excitation: 313 nm, FS
Sample: bright orange

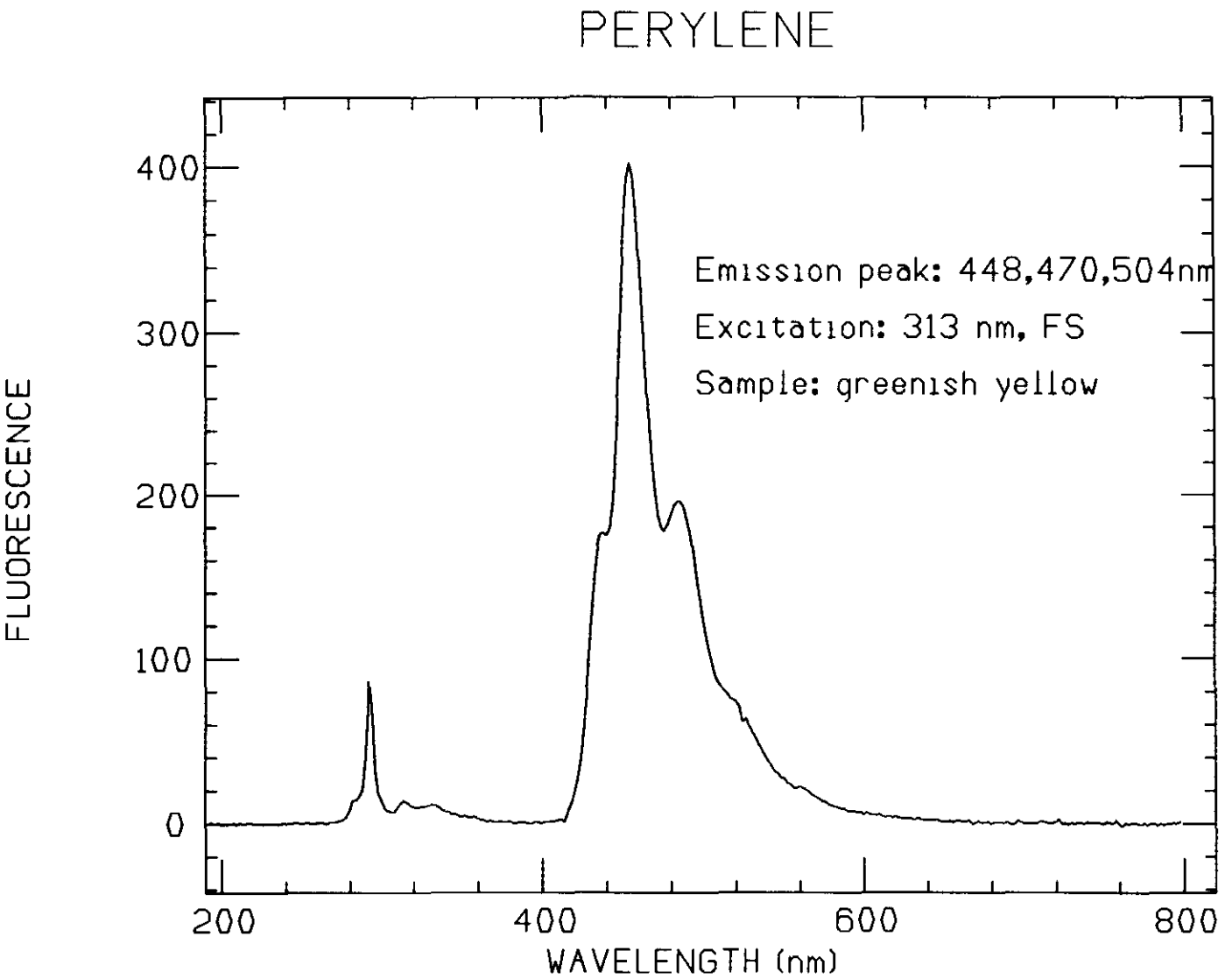

LD 688
Emission Peak: 588 nm
Excitation: 360 nm, BS
Sample: bright orange
FLUORESCENCE
100
50
0
200
400
600
800
WAVELENGTH (nm)

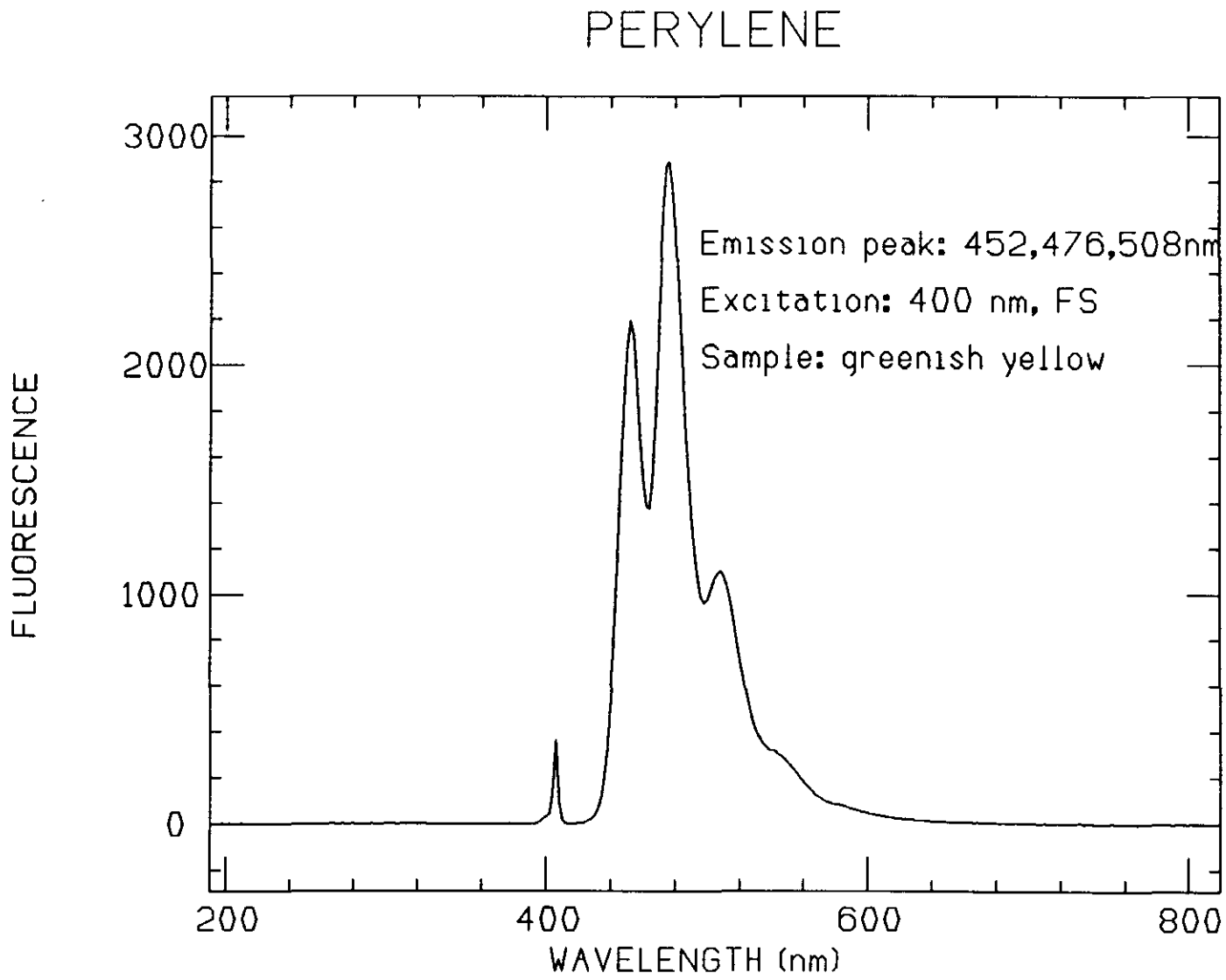

LD 688
Emission Peak: 586 nm
Excitation: 450 nm, BS
Sample: bright orange
FLUORESCENCE
150
100
50
0
200
400
600
800
WAVELENGTH (nm)


LDS 722 + C-E
Emission peak: 516 nm
Excitation: 313 nm, FS
Sample: pink
FLUORESCENCE
200
100
0
200
400
600
800
WAVELENGTH (nm)

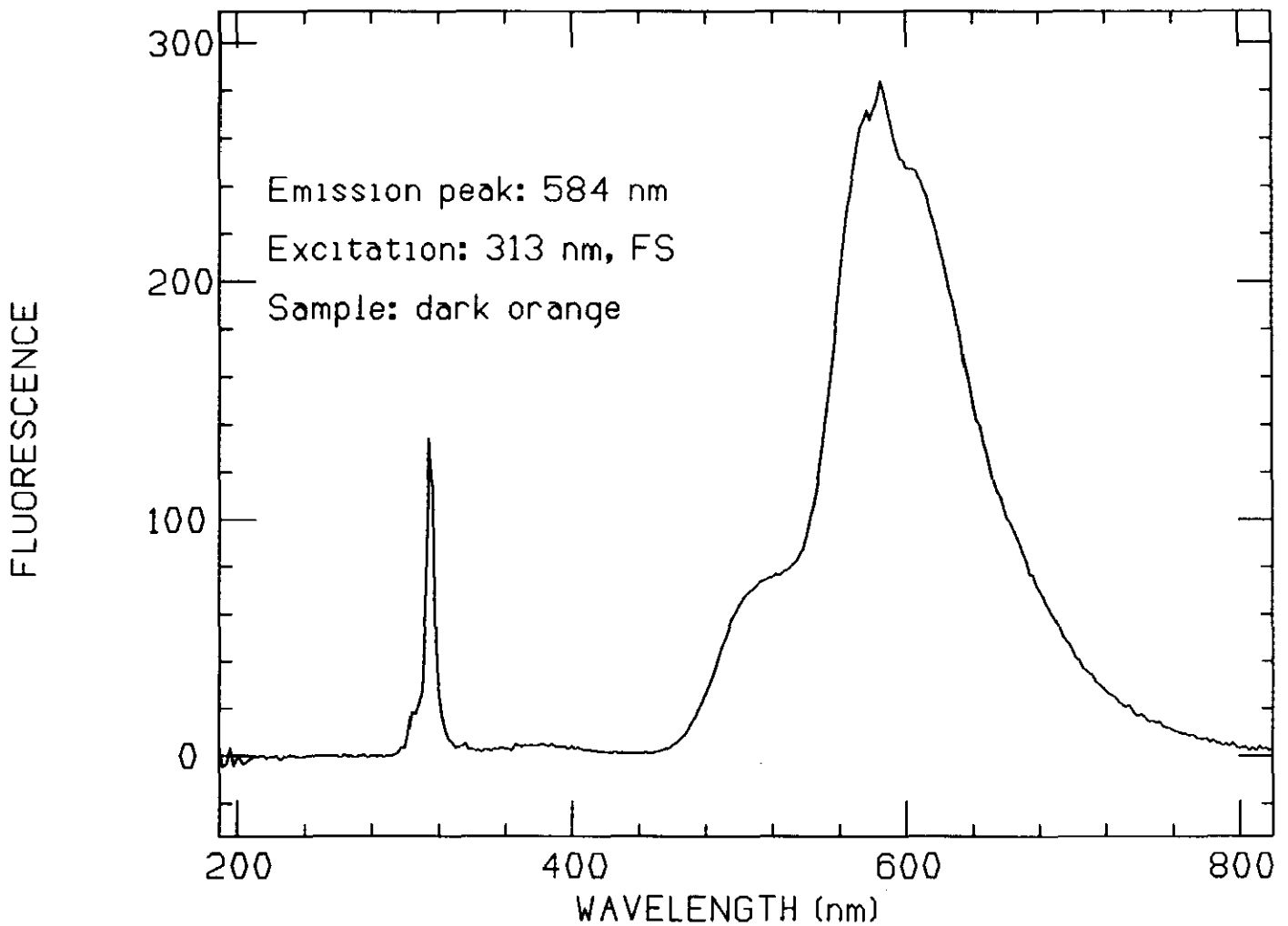

LDS 730 + C-E
Emission peak: 384,424 nm
Excitation: 313 nm, FS
Sample: pink
FLUORESCENCE
40
20
0
200
400
600
800
WAVELENGTH (nm)

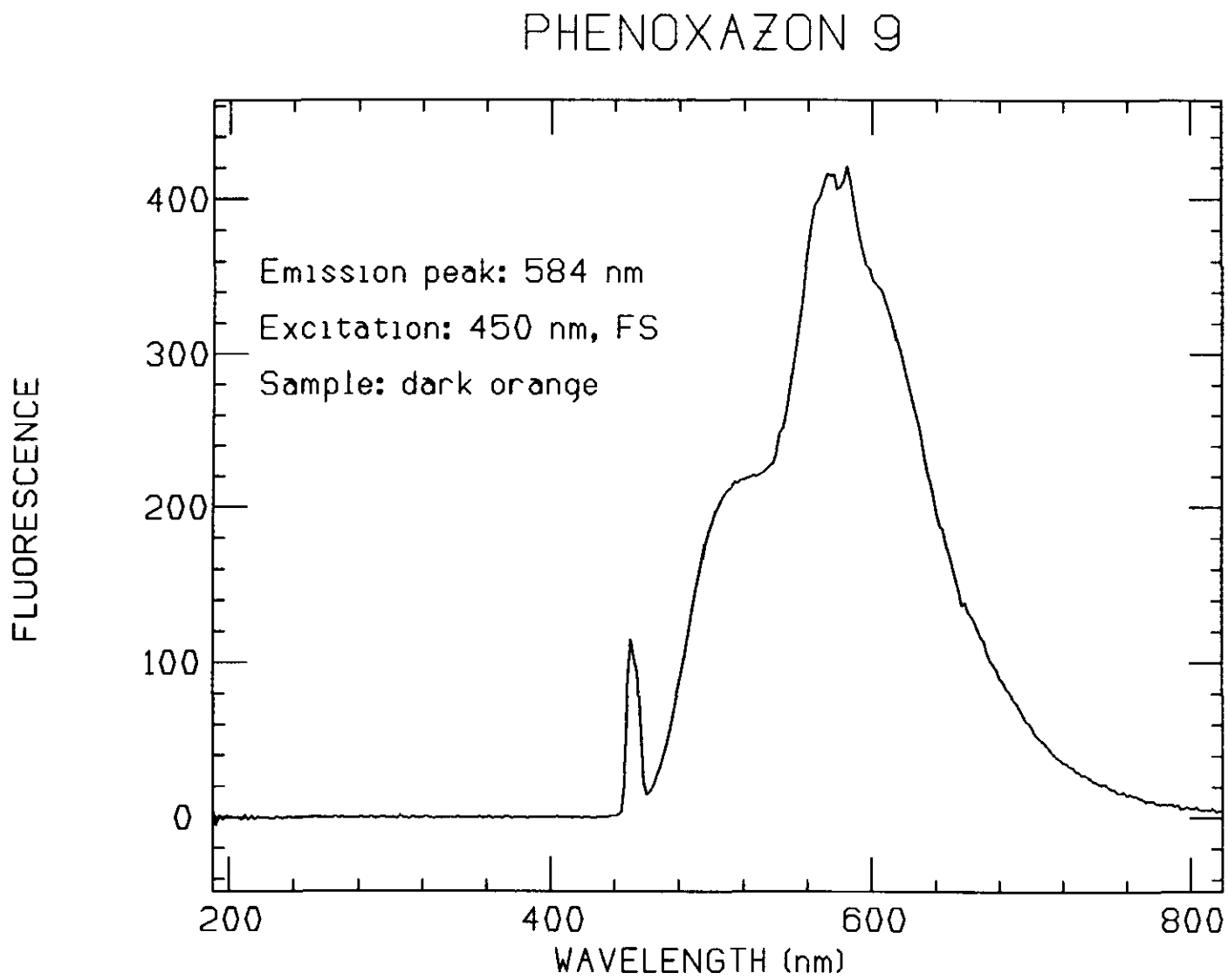

LDS 750 +C-E
Emission peak: No Light
Excitation: 313 nm, FS
Sample: clear
FLUORESCENCE
100
50
0
200
400
600
800
WAVELENGTH (nm)

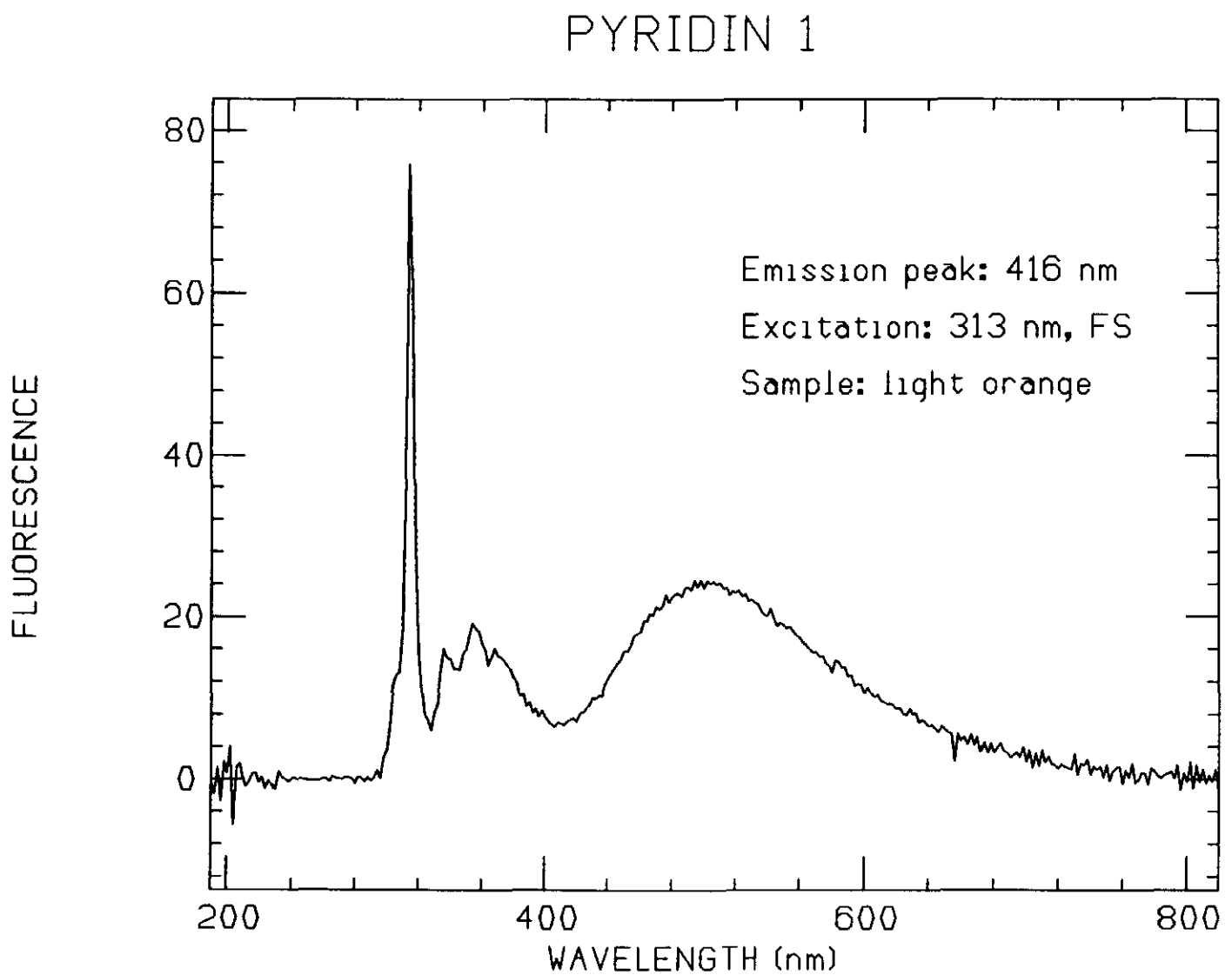

PERYLENE
FLUORESCENCE
400
300
200
100
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 448,470,504nm
Excitation: 313 nm, FS
Sample: greenish yellow


PERYLENE
FLUORESCENCE
3000
2000
1000
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 452,476,508nm
Excitation: 400 nm, FS
Sample: greenish yellow

PHENOXAZON 9




PHENOXAZON 9
Emission peak: 584 nm
Excitation: 450 nm, FS
Sample: dark orange
FLUORESCENCE
400
300
200
100
0
200
400
600
800
WAVELENGTH (nm)


PYRIDIN 1
FLUORESCENCE
80
60
40
20
0
200
400
600
800
WAVELENGTH (nm)
Emission peak: 416 nm
Excitation: 313 nm, FS
Sample: light orange