TRANSVERSE BEAM MATCHING USING WIRE SCANNERS*

by

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ABSTRACT

In order to avoid excessive beam loss in the 805-MHz portion of LAMPF, it is necessary to match the beam emittance to the acceptance of the linac. This is achieved by minimizing the oscillation amplitube of the rms beam widths as measured by wire scanners.

Because of the high design intensity (1 mA) of the beam in the Los Alamos accelerator, the percentage loss above 100 MeV must be kept extremely small. Consequently, in addition to the beam being well steered through the linac, it is important to have the emittance of the beam matched to the acceptance of the linac.

A straightforward procedure has been developed for matching the beam to the 805-MHz portion of LAMPF. The procedure has been programmed for the SEL 840-MP controls computer, and uses wire scanners to determine the horizontal and vertical widths of the beam at various locations along the linac. The matching procedure does <u>not</u> depend on knowing either the emittance of the beam or the acceptance of the linac.

The matching procedure is based on the following factors:

1. The 805-MHz portion of LAMPF (which starts at 100 MeV) is an "almost periodic" structure, where each period consists of one accelerating tank and an intertank space containing a quadrupole doublet.

2. The width of the matched beam, measured at homologous points along the structure, should be a slowly varying function of distance along the linac.

3. If the beam is not matched to the accelerator, then the beam width will oscillate about the width of the matched beam.

The matching procedure is as follows:

1. Measure the root mean square (rms) beam widths (in both the horizontal and vertical planes) using wire scanners located near the entrance of a number of successive accelerating tanks.

2. Change several upstream quads, one at a time, and remeasure the rms widths to empirically determine the partial derivatives of the beam widths with respect to each quad strength.

3. Fit the beam widths to a straight line (one line for horizontal widths, and one for vertical) to estimate the matched widths at each scanner location.

4. Using the generated partial derivatives, estimate new quad values that should minimize the amplitude of oscillation about the matched widths.

5. Iterate until satisfied with the match.

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To be more specific, let x_i^0 and y_i^0 be the horizontal and vertical rms widths, respectively, measured at the ith wire scanner before any upstream quads are changed. Let n denote the number of wire scanners, and let m denote the number of quads to be varied. The n wire scanners are run m + 1 times to accumulate the partial derivatives of the widths with respect to the m quads. Since the beam widths measured in each of the m + 1 runs should oscillate about the same matched widths, the data from all of the runs are used to estimate the matched widths.

The matched widths are assumed to have the form

$$\hat{x}_i = \hat{x}_1 + s_x(i - 1) \quad ,$$

and

$$\hat{y}_i = \hat{y}_1 + s_y(i - 1) \quad , \; i - 1,2,\ldots,n \quad .$$

The parameters $\hat{x}_1$, s_x, $\hat{y}_1$, and s_y are determined by a least squares fit to the data.

For quad values near the original settings, the widths at the ith wire scanner can be approximated by

$$x_i \approx x_i^0 + \sum_{j=1}^{m} \frac{\partial x_i}{\partial q_j} \delta q_j \quad ,$$

and

$$y_i \approx y_i^0 + \sum_{j=1}^{m} \frac{\partial y_i}{\partial q_j} \delta q_j \quad ,$$

where q_j is the strength of the jth variable quad. The estimated changes in the quad values, δq_j, are then found by minimizing the expression

$$R \equiv \sum_{i=1}^{n} \left[\left(1 - \frac{x_i}{\hat{x}_i}\right)^2 + \left(1 - \frac{y_i}{\hat{y}_i}\right)^2 \right]$$

with respect to the δq's.

This procedure has been successfully used to match the 100-MeV beam into the side-coupled linac. Starting at the second tank of the side-coupled structure, a wire scanner is located approximately 6 cm in front of each tank for 12 successive tanks. Figure 1 shows intensity profiles (horizontal in the left, vertical on the right) generated by these wire scanners before the first attempt at this matching procedure. (The horizontal profile at wire scanner 5-4 was missing because of hardware problems.) The beam was not being accelerated in the side-coupled linac. The beam was obviously not matched, as can be seen by the oscillations in the widths.

Figure 2 shows the intensity profiles after the matching procedure was used. During this first attempt at matching, the procedure differed from that described in that the estimated matched widths were simply the average widths. In addition, it was discovered at a late date that the horizontal and vertical signals were interchanged at wire scanner 7-3. Nevertheless, there was an obvious improvement in the match.

The final two figures show matched beam profiles. Figure 3 shows the situation when the beam is not being accelerated in the side-coupled linac; Fig. 4 shows profiles for the matched beam when the beam is being accelerated.

To conclude, our success with this matching procedure has given us added confidence that we will be able to meet the design intensity of LAMPF with neglibible beam loss above 100 MeV.

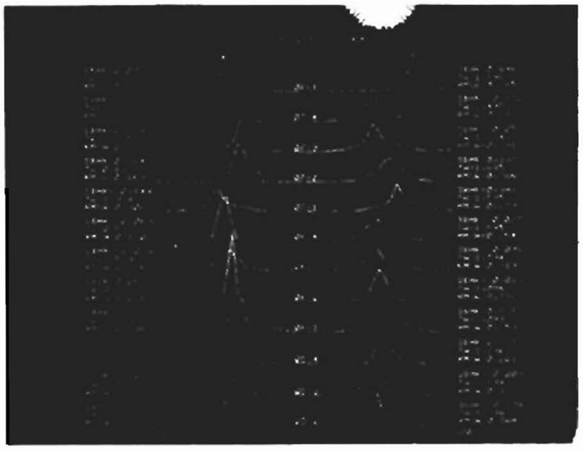

Fig. 1. Horizontal and vertical intensity profiles before matching was attempted.

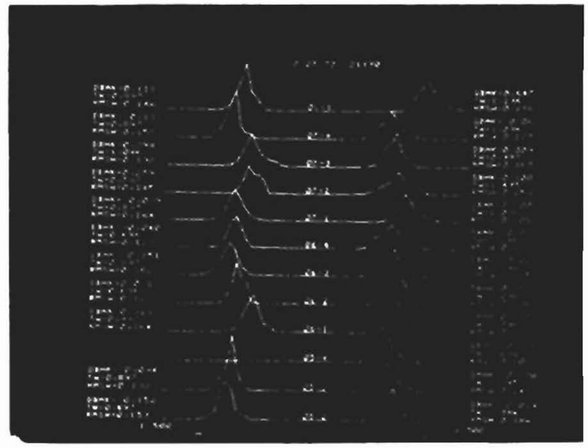

Fig. 2. Intensity profiles after first attempt at matching an unaccelerated beam

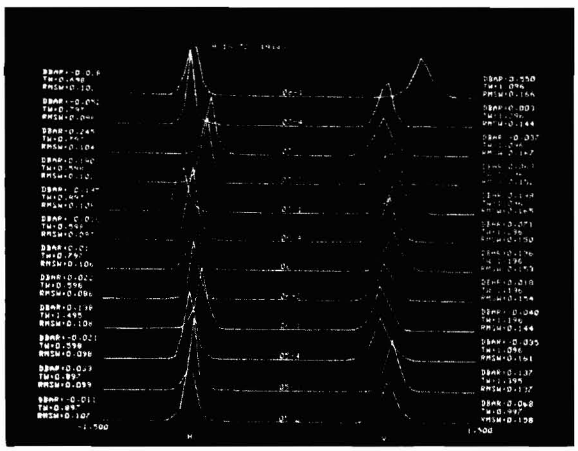

Fig. 3. Intensity profiles indicating a well-matched unaccelerated beam.

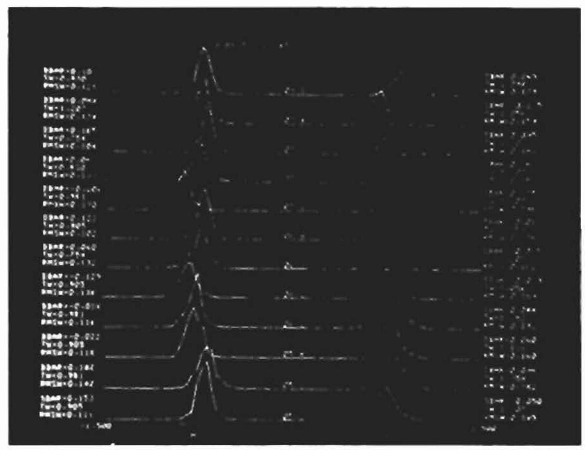

Fig. 4. Intensity profiles after first attempt at matching an accelerated beam.