Estimate of Pressure Beams for Electron Cooling Device

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7 September 1979

We would like to draw attention to an effect which can limit electron current in electron device for electron cooling method. For getting "fast damping" it is necessary to have large electron currents of order of ten amperes. These devices are schematically represented in the following drawing:

Fig 1.
Collector and gun are under negative high voltage (\( \sim \) 100 kV). In the electron beam ionized residual gas and ions move along electron beam to gun and collector. Ions accelerate toward the gun and collector and bombard their surface with energies of order \( \sim \) 100 kV. Ion sputtering yields for metals of order ten per ion in this range of energy. Sputtering and desorption molecules are fed back into the residual gas resulting in the possibility of creating an unstable run-away pressure increase. This increase finally destroys the electron beam. Let us estimate this process for a simple scheme.

![Diagram](image)

**Fig 2**

Flux of sputtering atoms from surface is equal to:

\[
\frac{d\Omega}{dt} = \varphi + \frac{J_e}{e} \sigma \int_{0}^{L} n(x) \, dx \tag{1}
\]
Where $q$ is the normal hot wall outgassing rate, plus electron desorption $I_e$ electron current, $e$ electron charge, $\sigma$ ionization cross section, $\eta$ sputtering and desorption co-efficient, $h(x)$ the gas density, $L$ distance between gun and pump. Gas density $h(x)$ can be defined from the gas flow

$$h(x) = \frac{dQ}{dt} \frac{1}{C} (1 - \frac{x}{L}) \quad (2)$$

$C$ is conductance for a tube with diameter $D$ and length $L$.

$$C = \frac{1}{6} \left( \frac{2 \pi kT}{m} \right)^{1/2} \frac{D^3}{L}$$

$K$ is Bolzman constant, $T$ is temperature, and $M$ is the atomic mass. Substituting Eq 2 in Eq 1 and integrating we have:

$$\frac{dQ}{dt} = \frac{q}{1 - \frac{I_e e \sigma h}{C} \left( \frac{1}{L} \right)} \quad (3)$$

One can see from (3) that the electron current must be less than:

$$I_e < \frac{e C \left( \frac{2 \pi kT}{m} \right)^{1/2} D^3}{3 \sigma \frac{e \hbar K}{L^2}} \quad (4)$$

The "pressure Bump" described by this threshold current is similar to the effect observed in the CERN storage ring.
For example if \( L = 300 \text{ cm} \), \( D = 10 \text{ cm} \), \( \sigma = 2 \times 10^{-17} \text{ cm} \)

(20 kV electron energy)

argon \( M = 40 \) T = 300° K = 90° F and \( \hbar = 1 \) the equation gives the threshold current:

\[
J_e < 1.74 \text{ A}
\]

Sputtering and desorption yields strongly depends on surface preparation and can change from 0.1 to 20. One can see from equation (4) that pumps should be located as close as possible to the electron gun and to the collector. In this case \( L \sim D \) the threshold current will be more than 1000 A.