SYNCHROTRON RADIATION VACUUM CHAMBER INSTALLATION AND BEAM SIZE*

M. Shleifer
National Synchrotron Light Source
Brookhaven National Laboratory
Upton, New York 11973

Introduction

In this paper we address the question of storage ring vacuum chamber placement and its effect on the synchrotron radiation fan obtainable. We consider only horizontal errors and thus treat the problem two-dimensionally. Specifically, we describe the correlation between the parameters of the chamber and its position in the magnet and the size of the fan of radiation emerging from a port.

General

A typical vacuum chamber with a welded port and a water cooled mask rigidly fixed to the port is shown in Fig. 1. The radiation first passes through an aperture in the vacuum chamber and then is defined by a water cooled mask.

We define a system of coordinates whose center (Fig. 1) is positioned at the center of the circular path described by the electrons. The fiducial point "F" of the chamber "ABCD" is positioned on the Y-axis.

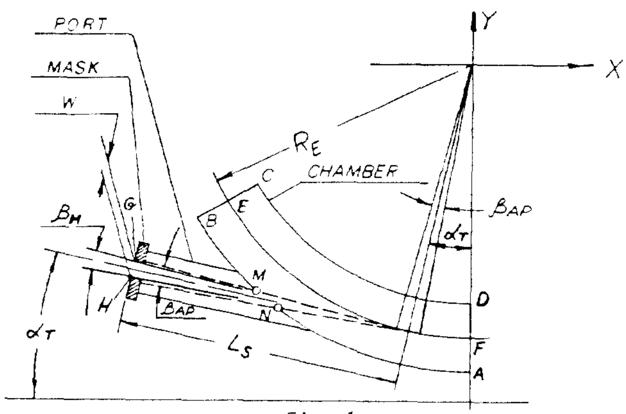

Fig. 1.

The size of the fan of radiation which emerges through the aperture of the vacuum chamber β_{ap} is defined by its edges "M" and "N".

According to Fig. 2 any point "P" with coordinates "X" and "Y" will see light making an angle α with the x-axis, given by

$$\alpha = \sigma - \Omega,$$

where $\sigma = \tan^{-1}(X/Y)$
and $\Omega = \cos^{-1}(Re/\sqrt{X^2 + Y^2})$,
where Re = radius of electron orbit.

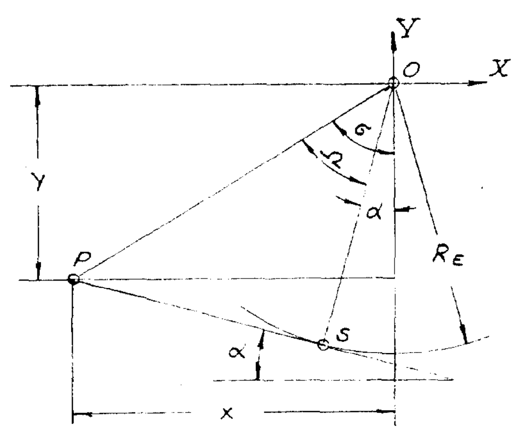

Fig. 2.

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As a result:

$$\alpha = \tan^{-1}(X/Y) - \cos^{-1}(Re/\sqrt{X^2 + Y^2}) \qquad (1)$$

Thus, the angular spread of the beam and its direction can be calculated if the coordinates of the four edges (aperture and water mask) are known.

We now address these in turn.

Water Mask

We obtain the coordinates of the water mask from a measurement, "Q", of the error in placement of its center. "Q" is measured from the nominal position perpendicular to the axis of the port. "Q" is positive if the water mask is away from the ring. The coordinates X_g, Y_g and X_h, Y_h of G and H are then given by:

$$X_g = -Re*\sin\alpha_T - L_S*\cos\alpha_T + (.5*W-Q)*\sin\alpha_T,$$
$$Y_g = -Re*\cos\alpha_T + L_S*\sin\alpha_T + (.5*W-Q)*\cos\alpha_T,$$
$$X_h = -Re*\sin\alpha_T - L_S*\cos\alpha_T - (.5*W+Q)*\sin\alpha_T,$$
$$Y_h = -Re*\cos\alpha_T + L_S*\sin\alpha_T - (.5*W+Q)*\cos\alpha_T,$$

where: L_S = Distance from source to the center of the aperture,
α_T = Theoretical angle of the beam line,
W = Size of the aperture in mm.

Aperture

The coordinates of the edges of the installed chamber aperture may be calculated from the measured positions of the fiducial points.

In Fig. 3 the fiducial point located at E(xe,Ye) on the chamber "ABCD" differs from its nominal position by a distance "a" in the x-direction and by a distance "b" in the y-direction; the fiducial point F(Xf,Yf) differs by a distance "c" in x-direction and by a distance "d" in y-direction:

$$X_e^1 = X_e + a;$$
$$Y_e^1 = Y_e + b;$$
$$X_f^1 = X_f + c;$$
$$Y_f^1 = Y_f + d.$$

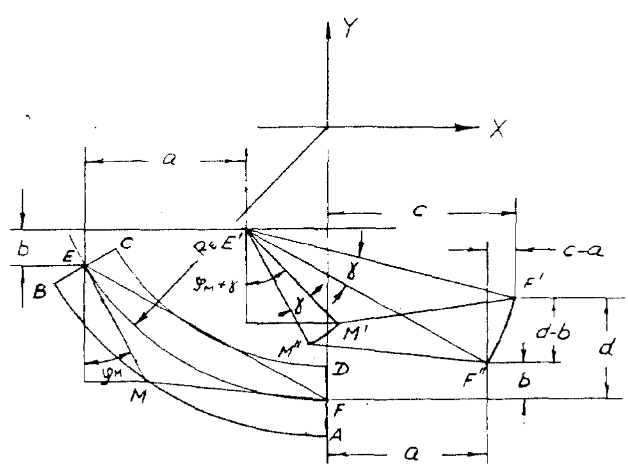

Fig. 3

In order to calculate the coordinates of M and N we consider the chamber movement away from its nominal position to take place in two steps.

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1. Parallel to itself from "EF" to "E'F''" (each point of the chamber moves by "a" in x-direction and by "b" in Y-direction).

2. Rotation around the point E' by the angle γ from position "E'F''" to position "E'F'", where

$$\gamma = \sin^{-1} \frac{c-a}{L*\sin \tan^{-1} \left(\frac{c-a}{d-b}\right)} \qquad (2)$$

All points of the chamber move by the same amounts "a" and "b" and rotate by the same angle γ around point E'.

The coordinates of the edges "M" and "N" in installed chamber position are then:

$$X_m = X_e + a + L_m*\sin(\phi_M + \gamma);$$
$$Y_m = Y_e + b - L_m*\cos(\phi_M + \gamma);$$
$$X_n = X_e + a + L_n*\sin(\phi_N + \gamma);$$
$$Y_n = Y_e + b - L_n*\cos(\phi_N + \gamma);$$

where:

$$\phi_m = \tan^{-1} \left| \frac{X_m - X_e}{Y_m - Y_e} \right| ; \qquad (3)$$

$$\phi_n = \tan^{-1} \left| \frac{X_n - X_e}{Y_n - Y_e} \right| ; \qquad (4)$$

$$L_m = \sqrt{(X_e - X_m)^2 + (Y_e - Y_m)^2} ; \qquad (5)$$

$$L_n = \sqrt{(X_e - X_n)^2 + (Y_e - Y_n)^2} . \qquad (6)$$

Summary

Knowing the coordinates of both the aperture M,N and the mask G,H, we can now use equation (1) to calculate the radiation angles and hence derive the size of the total fan and its angle.

According to our experience in order to guarantee a full size fan it is desirable to make:

$$\beta_{ap} \geq 1.2\ \beta_m,$$

where β_m = beam through the water mask aperture.

At the NSLS we almost always have full size beam in even numbered ports for which $\beta_{ap} = 1.22\ \beta_m$, however for odd ports, where the relationship is: $\beta_{ap} = 1.08\ \beta_m$, we typically extract only about 70 mrad instead of the expected 80 mrad.

Acknowledgement

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