

DUKE STORAGE RING TUNE MEASUREMENTS SYSTEM USING RAZOR BLADE AND PHOTOMULTIPLIER*

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Abstract

We present in this paper the description of the Duke storage ring tune measurements system. An unusual feature of this system is the use of synchrotron radiation to sense oscillation of the electron beam. This system includes a lens, a razor blade placed at the focus and a photomultiplier. Our experience shows that this system can operate on -70 dBm level and detect electron beam oscillations as small as one micron.

I. INTRODUCTION

The 1.1 GeV Duke electron storage ring [1] has four end-of-arc ports for extraction of synchrotron radiation. The visible part of this radiation is used for optical diagnostics of the electron beam. It includes optics (mirrors, lenses, beam-splitters), TV cameras, screens, a dissector with 20 psec resolution, and a number of photomultipliers. Each corner is equipped with a small optical table to mount optical components. We use these elements to build a tune measurements system.

II. TUNE MEASUREMENTS SYSTEM

Schematic of the Duke storage ring tunes measurement system is shown on Fig.1. It is based on surplus equipment:

HP-8443A tracking generator and HP-8553 spectrum analyzer with 110 MHz range. Some parameters of the Duke storage ring are listed in Table 1.

Table I. Main Parameters of Duke Storage Ring

Operation energy [GeV]	0.2 - 1.1
Ring circumference [m]	107.46
Revolution frequency [MHz]	2.7898
RF frequency [MHz]	178.547
Betatron tunes, Qx and Qy	9.111, 4.180

The excitation part.

The excitation part consists of the tracking generator, 1W amplifier and a transformer attached to two short mismatched BPM striplines. The Duke storage ring has 60 stripline BPMs which do not have electronics. Four BPM striplines are located at 45° with respect to the median plane. They are 2.5 cm long and are shorted at one end. There are two types of BPMs- arc BPMs with 2 cm internal radius and straight section BPMs with 5 cm internal radius. The coupling of these striplines with the electron beam is efficient at very high frequencies (few GHz) where the cost of the tune measurements system is very high.

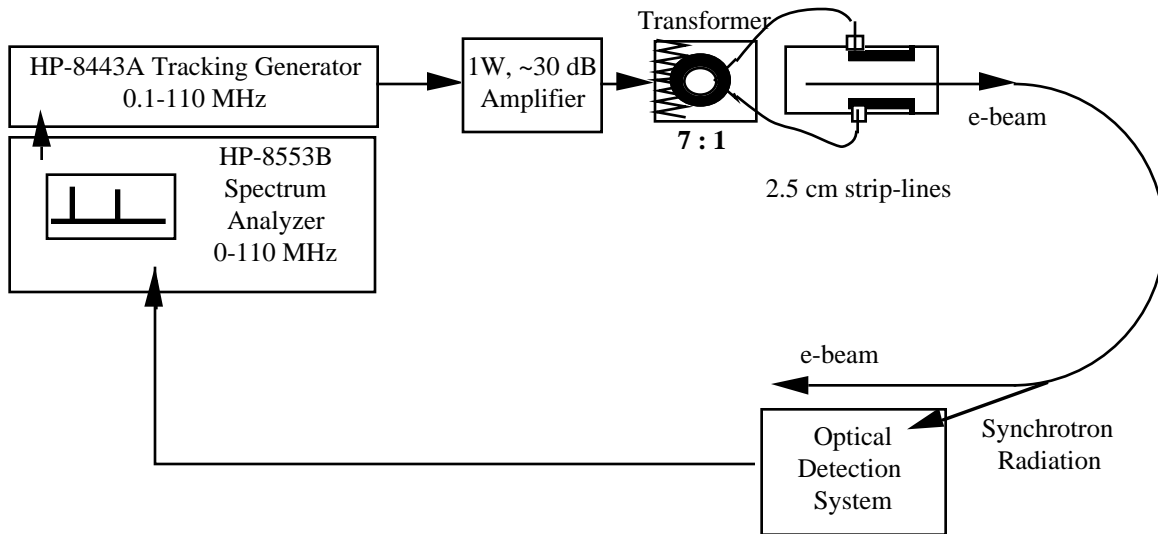


Fig. 1 The Duke Storage Ring Tunes Measurement System

*Work supported by ONR grant #N00014-94-1-0818

We use the pure magnetic coupling at low frequency (<1.5 MHz) in the excitation system. An 1 W, a 30 dB

amplifier is loaded on ferrite 7:1 transformer for better matching. This scheme also improves excitation efficiency at low frequencies by increasing current through the striplines. The transformer is attached to two opposite

striplines to excite a dipole AC magnetic field. The magnetic field is directed at 45° with respect to the median plane and can be used to excite both horizontal and vertical oscillations. The system has a bandwidth of 5 MHz, which is larger than we need. This system excites an electron beam oscillation when the frequency of the tracking generator f_{TG} matches one of betatron frequencies:

$f_{TG} = f_{rev} \cdot (N \pm \{Q_{x,y}\})$, where f_{rev} is revolution frequency and $\{Q_{x,y}\}$ is a non-integer part of one of betatron tunes and N is an arbitrary integer number. We use $N=0$ and the most useful tracking generator range for our ring is 200-800 kHz.

The performance of the above system was very satisfactory. This system can excite 1 to 2 mm beam oscillations at 1 GeV when operated at 5 dBm of tracking generator output. We initially used this system in a manual mode in which resonance was determined by the increase in the beam size monitored by a video camera. Later we switched to an automated mode with an optical detector.

The detector part - the razor blade with photomultiplier.

We take advantage of the available visible light to build a simple, elegant, very sensitive and inexpensive system for tune measurements. The schematic of this system is shown on Fig.2. The detection system includes the lens which focuses light emitted by the electron beam on the razor edge. The razor is located on 2D stage. Longitudinal adjustment is used to place the razor exactly at the focal plane, where the image of the electron beam is

created by the lens. This image follows the motion of the electron beam and can be used to detect its oscillations. Transverse adjustment is used to locate the razor edge at the center of beam image. This degree of motion is remotely controlled from the storage ring control room.

The photomultiplier is located behind the razor. Its window and photo-cathode is large enough to detect all light passing the razor blade. The razor blade is installed at 45° and cuts the half of the beam image as shown on Fig. 3. It is natural to use an angle of 45° to be sensitive to both horizontal and vertical oscillations of the electron beam. To adjust the razor on the middle of the beam image we use the DC signal from the photomultiplier: we move the razor blade out to let all light to pass and then move it to the position when the DC signal decreases by a factor of two. There is drastic difference in AC response of the photomultiplier: when the blade is out, the signal from photomultiplier is pure and repeatable; when the blade cuts the image in half, the system becomes very sensitive to small motions of the electron beam.

When the electron beam position oscillates with frequency f_{beam} , horizontally or vertically, it modulates the intensity of the light falling on the photomultiplier. The spectrum of the photomultiplier signal will contain the same frequency shifted by harmonics of the revolution frequency: $f = f_{beam} \pm Nf_{rev}$. The harmonic content depends on the filling pattern of the electron beam and the bandwidth of the photomultiplier.

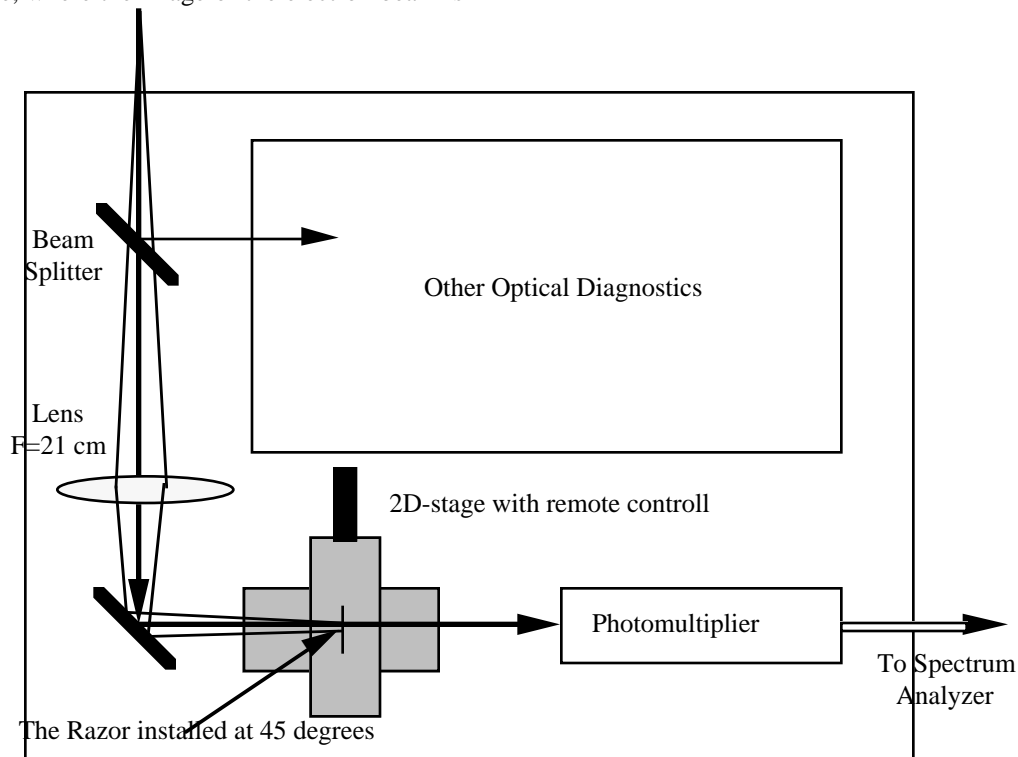


Fig. 2 Optical detection system for tunes measurements.

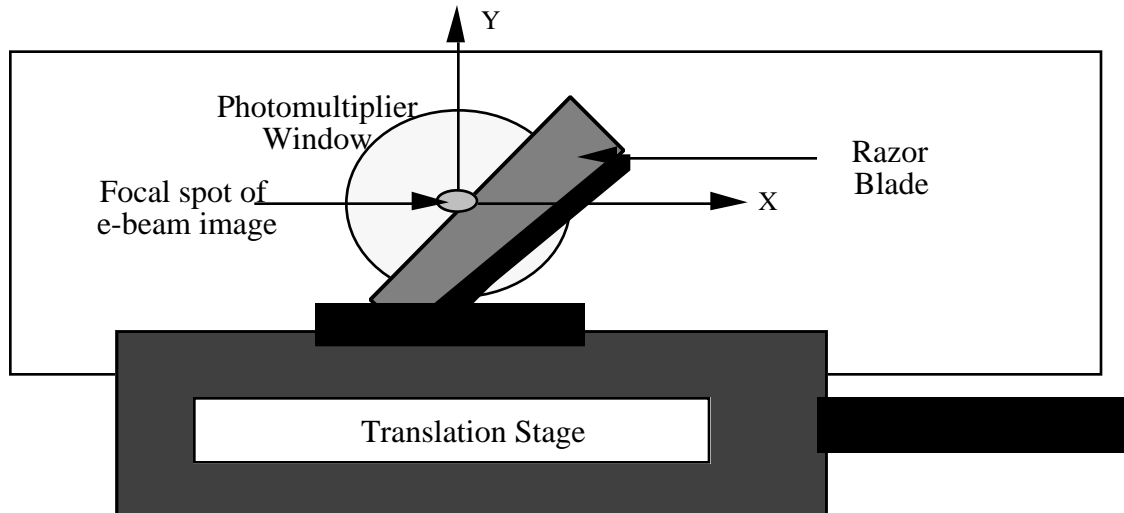


Fig. 3 Ideal positioning of e-beam image on the razor blade for detector of dipole oscillations.

We use the zero-th harmonic whose amplitude is proportional to the average electron beam current and the amplitude of oscillations.

We use a very common 931-A photomultiplier in our system with bandwidth of about 30 MHz. Control of its 1.2 kV high voltage power supply (as well as other photomultipliers) is a part of the storage ring computer control system. Thus, we can always set an optimal operating point of the photomultiplier.

III. CONCLUSIONS

The typical electron beam size in the Duke storage ring is 100-400 microns. It means that oscillations of electron beam with an amplitude of one micron can be detected easily. We tested the performance of the system described above with a wide range of the electron beam current and energies in the Duke storage ring. The system performed perfectly. With 1 kHz bandwidth of the spectrum analyzer, the system has betatron peak 3 dB above the noise level with -70 dBm amplitude (tracking generator output). It means that this system can easily detect an electron beam oscillation as small as 0.5 microns. With -50 dBm signal level, the betatron peaks are very clean without any noticeable noise. The performance is remarkable for a detection system costing less than two thousands dollars.

We are planning further improvements to the detection system, i.e. to make detector self-adjustable using feedback from a segmented photodiode to control the image position on the blade. In addition, a simple DC feed back system will automatically control the photomultiplier gain. This system (sketched on Fig. 4) would not require any operator assistance: it will provide constant sensitivity in wide range of beam currents (0.01 mA to 1 A) and beam positions (± 1 cm in both directions).

Authors are thankful to Steve Kramer provided for preliminary test of this system at VUV ring (BNL). We would also like to thank Ping Wang, Carl Dickey, Joe Faircloth, Jim Meyer, and Owen Oakeley for helping assembling this system.

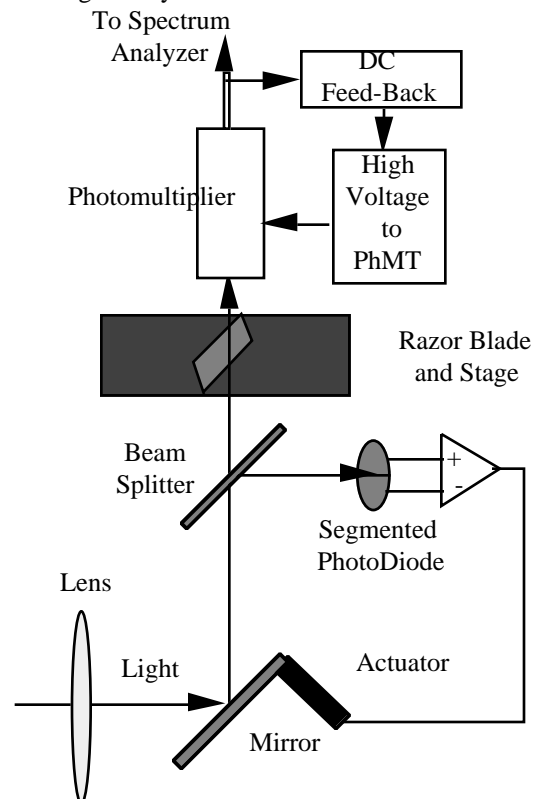


Fig. 4 Self-adjusted detection system.

IV. REFERENCES

- [1] V.N.Litvinenko et al., "Commissioning of the Duke Storage Ring, These Proceedings.