# AN IONIZATION DETECTOR OF SYNCHROTRON BEAM SPATIAL PARAMETERS: POSSIBLE APPLICATIONS

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## ABSTRACT

The ionizing Beam Cross-section Image Detector (BCID) is developed. The detector can measure the shape, the size and the profile, the position and angle of a SR beam without any influence on it. BCID is installed into separate vacuum chamber with Be windows. For better sensitivity the chamber is filled with Ar or Xe under the pressure about $10^{-3}$ - $10^{-4}$ Torr. The detector was checked on SR beams of the next storage rings: DCI (LURE, Orsay, France), KSRS (RRC KI, Moscow, Russia) and MAX-2 (MAX-lab, Lund, Sweden). All these experiments showed high sensitivity and good resolution of the detector and clear images of the beam cross-section. Summation of big amount of TV frames was used. This method increases signal to noise ratio. Resulting image is saved in computer for further processing. Uncertainty of some microns was achieved for SR beam gravity center while the size of the beam was about two millimeters. The results achieved can be used for registration of ionizing beams on accelerators of different types.

## 1. INTRODUCTION.

On line control of SR beam position and size is very important. Photo emission scanners, edge diaphragms and the systems of orthogonal wires with photoemission current measurement are widely used. There exist foils with scintillator placed across the beam, TV cameras, position sensitive photodiodes arrays and other detector types.

Nevertheless it is very urgent to create the new detectors types. It is very natural to try using the ionizing Beam Cross-section Image Detectors (BCID) developed before [1 – 2]. These detectors can fulfill on line control of the shape, the size and profile of an ionizing beam, density distribution across the beam, the position and the displacement of the beam gravity center and the angle of a beam without any influence on the beam. Such devices work very well on accelerators of charged particles [3-4]. Structure of the BCID was described minutely in [3 – 5] so let us remind only the working principle.

BCID registers electrons or ions created by the investigated beam in residual gas. Extractor electric field draws out ions through the narrow slit into the analyzer. The analyzer electric field transforms the energy distribution of ions created by extractor electric field into the space distribution. Then, there is open Image Converter Tube (ICT) that is made of two Micro Channel Plates (MCP). Image of the real beam cross section is formed on output luminescence screen of ICT. This image are registered by TV camera, presented on monitor and processed by a computer. Vacuum chamber with the detector is separated from the atmosphere and a beamline by Be windows.

First experiments on registration of SR beam with the help of BCID were published [4-5].

When using Argon or Xenon as working gas instead of the air sensitivity estimated can be increased more then one order of magnitude. So the energy and intensity band to use BCID can be much wider. Now we give our new results.

## 2. HARDWARE, PROCESSING AND INFORMATION PRESENTATION.

TV monitor provides visual control of the SR beam shape, profile and position of a beam cross-section image. Simultaneously, TV images are digitized by some commercial electronics and saved into a computer with the frequency up to 12.5 Hz. The resolution of a frame is 256*256 points with 64 amplitudes levels. Frames are shown on a computer monitor with the frequency 12.5 Hz. The full amount of frames that can be saved in a computer is up to 256 in the next formats: Targa, GIF, and PCX.

We developed the software, which gives us on-line possibility of:

- discrimination of a background from each frame,
-presentation of vertical and horizontal profiles of a beam consisting of 128 points for every registered image,
- presentation of the averaged vertical and horizontal profile of the frame,
- integration up to 256 frames and corresponding increasing of absolute sensitivity and signal to noise ratio more then one order of magnitude,
- fitting by the least square method a Gauss distribution for every frame to find out the position of the beam;
- calculation of the dispersion of the distribution of the beam position (from Gauss fitting results);

- summation of the results for up to 256 frames;
- calculation of the average position of the beam, it's dispersion and statistic errors (from Gauss fitting results);
- calculation of the gravity center for each frame as alternative to Gauss fitting method,
- further data processing similar to those for Gauss fitting,
- comparison of the results for different methods processing of the beam center.

## 3. EXPERIMENTS ON SR BEAMS REGISTRATION.

The first experiments were carried out on a white beam of the storage ring DCI (LURE, Orsay, France) [5]. The experiment conditions were the following: electron energy - 1.5 GeV, electron current - 200 mA, SR critical energy - 3.5 keV, the distance from emitting point - 15.5 m. These measurements confirm the possibility of SR beam characteristics registration with the help of BCID.

The next experiments were carried out on a white beam of the storage ring KSRS (RRC KI, Moscow, Russia). The experiment conditions were the following: electron energy - 2.5 GeV, electron current - from 2 up to 25 mA and SR critical energy - 7 keV. The construction of the detector has some peculiarities. Vacuum chamber was made with metal sealing and baked out up to 150-180 C. It was found that working pressure of Argon $10^{-3}$ – $10^{-4}$ Torr was practically constant during some days. This will give possibility to pump the detector volume only from time to time and the detector will be simpler and cheaper.

Beryllium windows were located upstream 0.4m and downstream 1m from the detector. The size of non collimated SR beam was of order 2*40 $mm^2$.

Fig.1 gives the image of SR beam cross-section and profiles with $I_e$= 20mA after computer processing.

There is a background on Fig 1a. This background is distributed along the whole of a frame. The amplitude of this background gradually increases from the edges of a frame to the axes of the beam. The experiment shows that this background consists of two components. One of them is the inner noise of the TV camera. The second one is directly connected with SR beam. This part of the background increases with increasing of electron current of the storage ring. There exist some possibilities to relate this part to low angle scattering of SR on Be window. Regular nature of the background can be electronically discriminated from the initial picture (Fig.1b). Thus the position of the beam can be evaluated more carefully.

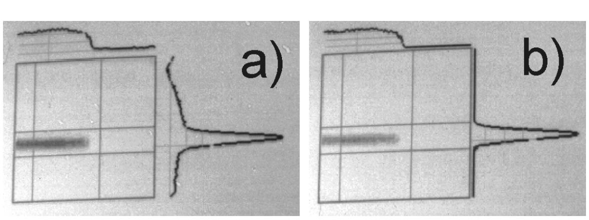


Fig.1 Image of SR beam cross-section and corresponding profiles a) before background discrimination, b) after background discrimination.

Fig.2 gives four single frames for different electron current of the storage ring. One can see that the image has statistic character when electron current is low. With the increasing of electron current the image became more regular. Fig 2a) and 2b) give evidence that it is not so good to control geometric parameters of a beam using such kind of the image. So, we created a code for summation and averaging of profiles for one frame and for a number of frames. It gives good results (Fig. 3.). Fig. 3a gives averaged image of 128 singe frames which correspond to the beam shown on Fig.2a.The size of the frame is 20*20 mm with the resolution of 128*128 channels.

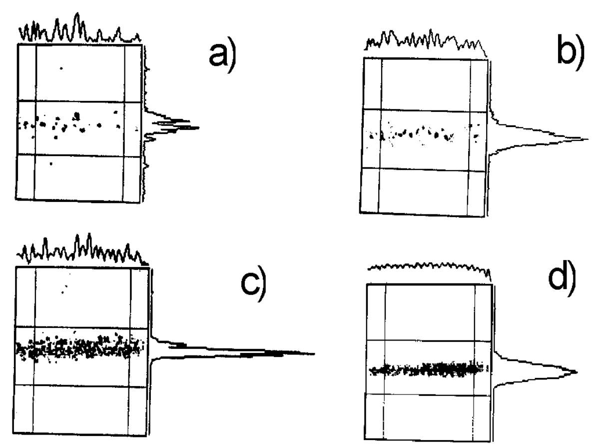


Fig.2 Image of SR beam and profiles on one TV frame for different storage ring beam current. a ) I= 2.5 mA, b) I=5 mA, c) I=10 mA, d) I=25mA

Let us note that for non-collimated white KSRS beam the vertical profile and its position are of the most interest. Computer code described above give the uncertainty of the beam center of about two micron when Ie=25 mA and measuring time is 12.5 second.

Fig 3b gives an example of averaged image of 256 single frames of monochromatized SR beam measured as described bellow. SR energy is 13.8 keV, size of the frame is 7*7mm, resolution 128*128 channels.

The experiments were carried out on BL711 beamline of the storage ring MAX-2 (MAX-lab), electron energy - 1.5 GeV, electron current – up to 200 mA. A multipole wiggler comprising 27 poles of permanent magnets with a peak field of 1.8 T generates radiation in the X-ray region with critical photon energy of 2.69 keV. Estimated SR flux at 15 keV is about $6*10^{12}$ ph/s, $\Delta E/E \cong 1*10^{-3}$.

There was focusing X-ray optic at the beamline. A bent mirror coated with platinum was placed at 10 m downstream the source point for focusing in vertical

direction. A bent asymmetrically cut single Si (111) crystal was placed 15 m downstream the source point for monochromatization and focusing in horizontal plane.
With the help of the detector focusing parameters of the mirror and the monochromator were optimized. It was done for three energies: 13.8; 12.4 and 9.5 keV (0.9; 1.0 and 1.3 A). The measuring time was changed from 5 to 20 seconds. At 1 angstrom (12.4 keV) and 150 mA current in the ring and with a beam size (slit size) of 0.3*0.3 $mm^2$ the measured absolute intensity was
$10^{11}$ ph/s.

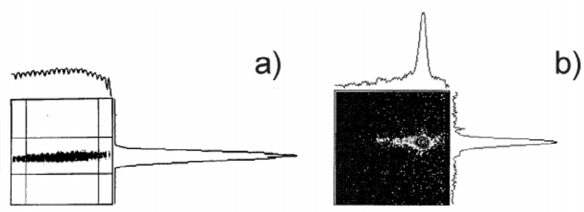


Fig.3. Image SR beam and profiles on averaged frame, a) white SR beam of KSRS, b) monochromatized SR beam of MAX-2 (see text)

So Fig. 3b gives the examples of monochromatic beam cross section images measured for the first time without any influence on the beam. The measurement shows that optimal focusing gives the possibility to obtain FWHM about 0.5mm what coincides with the calculated value.
Note that in the last experiment with the detector we used Xe under pressure about $10^{-3}$ - $10^{-4}$ Torr. Thus, sensitivity of the detector was much higher then in previous cases. Figures 1 a) and b), 2 a), b), c) and d) and 3 a) were measured with analyzer slit size 1 mm. Figure 3 b) was measured with analyzer slit size 0.15 mm.

## 4. CONCLUSION.

The experiments described above showed that it is possible to carry out on line visual and quantity control of SR beams. Information accumulation from different TV image frames, following averaging and processing gives the possibility to increase the sensitivity more then one order of magnitude in the wide ranges of energies and intensities. The measurement demonstrate the possibility to measure SR beams with the size of 1 mm and less. So it makes possible to fulfill two-axis focusing of monochromatic radiation from beamline BL711 of MAX-2 storage ring. High statistic precision of beam gravity center position up to some micron achieved. It is evident that two such detectors placed at the beginning and at the end of a beam line can measure beam axis with high precision. Such the monitoring is very important for example for deep lithography experiment carried out as one of micro technology step. It is evident that the results described can be used for monitoring of the charged particles beams of different kind accelerators.
The design of some standard types of BICD is under development. The codes for processing are in progress.

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