Abstract: A new technique for beam diagnostics using optical radiation, arising from a charged particle interaction with the wire crossing the beam, is proposed. Possibilities of using optical transition are considered.

Optical Radiation Sources

A luminescent wire with a high light yield and good radiation resistivity may be used as a scanning device. For instance the light yield of a wire 25 μm in diameter made from GSI, (CSD) [5] is 1.5 photons/keV, its decay time is 55 ns and the maximum of radiation occurs at the wave length 400 nm. The number of photons leaving the wire surface in 0.5 photons/sr. The heating of the wire caused by the beam may result in the attenuation of the luminescence. Therefore the range of its applicability is determined by the particle current ion density in the accelerator. In our calculations we took the particle distribution in the accelerator follows to Gaussian.

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As is seen from Fig.2 for the angles $\theta \gg 1/\chi$ the value for OTR is practically independent of the particle energy. For example, for $\theta \approx 70$ and the angle $\theta = -90$ mrad the radiation intensity is equal to $0.13$ protons/sr part. within the wave range $300-700$ nm. We have reliable experimental confirmations [6,7] of the fact that formula (2) describes nicely the OTR distribution at the particle interaction with thin films. At present there are neither experimental nor theoretical works, which describe OTR arising in the particle interaction with micro-objects. Rough estimates allow us to assume for the particle with $\chi \approx 300$ the transverse sizes of micro-objects should be larger than $20 \mu$m. Therefore it is of practical importance to study experimentally OTR in the interaction of the particle with $\chi > 300$ with objects of small sizes.

Since OTR is irradiated from the surface of the material, we have a possibility to use a ribbon of thin foil. This ribbon will make it possible to increase the integral luminosity and does not worsen the resolution. For instance, the foil $1 \text{ mm}$ wide and $1 \mu$m thick has the same cross section area as the wire of $30 \mu$m diameter, but the light yield is $28$ times higher than from the wire.

**TV Camera**

A digital television device with the vidicon LI-450 (XQ-1440) may be used as a detecting apparatus. It was used in the OTR investigations [6]. The cadmium selenid vidicon target possesses high quantum efficiency of $0.67$, the sensitivity is $S_\lambda(\lambda_m) = 0.37$ A/W in the maximum of the spectral characteristics ($\lambda_m = 580$ nm).

The digital TV system with the vidicon LI-450 has the current noise $0.1$ nA, which corresponds to $10^8$ photons/cm$^2$. The TV cameras using SIT and ISIT - vidicons [6] are widely used for beam diagnostics purposes. These devices have a high sensitivity and their threshold sensitivity is $4 \times 10^5$ and $2 \times 10^5$ photons/cm$^2$. Fig.3 shows the relative sensitivity for LI-450, SIT, SIT* ($*$ - spectral characteristics corrected for the long wave range).

**Heating**

During beam scanning with the wire there occurs the radiation heating. The heated wire turns out to emit heat energy, which may cause to errors in measurements. Since the shape of the temperature curve does not coincide with that of the beam. The temperature of the wire may be determined with the formula given in ref. 1. However this formula does not take into account heat emission from the surface and the dependence of the thermal physical coefficients on temperature. Bearing in mind the importance of this problem, we have carried out numerical calculations.

![Fig. 2. Spectral-angular OTR distributions as different energies: 1 - 14 GeV, 2 - 70 GeV, 3 - 800 GeV.](image)

![Fig. 3. Relative spectral characteristics: 1 - LI-450; 2 - SIT; 3 - SIT*; 4 - spectral OTR brightness of a body at $1900^\circ K$, $\alpha = 0.5$; 5, 6 - spectral OTR brightness at 67 mrad and $\chi = 288$ (5 - particle current density $0.44$ A/cm$^2$, 6 - particle current density $0.14$ A/cm$^2$).](image)

During scanning the wire temperature first increase and then after reaching its maximum starts falling down. The value and position of the temperature maximum depend on many parameters, among them are the beam density, wire scanning speed and its sizes. Fig.4 presents a typical wire temperature dependence during scanning, as well as the values of the signals from the photoreceivers versus heat emission and OTR.

![Fig. 4. Shapes of the photoreceiver signals, initiated by different types of radiation for CERN SPS ($L = 10^{13}$ p, $E = 270$ GeV, $\theta = 1.1$ mm, $d = 25$ mm, $\nu = 4.3$ m/s): 1 - wire temperature when scanning; 2 - OTR signal at 67 mrad; 3 - relative value for LI-450 from heat emission; 4 - relative value for SIT signal from heat emission.](image)
SIT* characteristics corrected so as to improve the detection conditions. This reduces the device sensitivity by 30%, but the ratio $I_T/I_0$ may be improved more than 10 times.

There are other ways to reduce the contribution from heat emission. For instance, in the case of the bunched beams, one may use bunch selection, and for OTR it will be a polarized filter. It should be noted that this is the way to single out only heat emission of the wire and hence to obtain the information about the temperature regime of the wire when scanning.

It is certain difficulty to give an analytic description of $I_T/I_0$ because of a great number of the parameters in this formula. For the estimate of $I_T/I_0$ one can use the plots presented in Fig. 5. Here the particle current in the machine has been found from the condition of equality of the transition radiation at the angle $\theta$ and heat emission with temperature $T$.

$$J = x(y)F(\theta) = \frac{J_{0}(\lambda, T)S_{p}(\lambda) d\lambda}{\int \frac{J_{0}(\lambda, T)S_{p}(\lambda) d\lambda}{\lambda^{2}}},$$

where $J(x,y)$ is the current density of a particle, $F(\theta)$ is a multiplier from formula (2), $a$ is the dark quotient. $L(\lambda, T)$ is the brightness of heat emission of a black body, $\xi(\lambda)$ is the photon energy.

**Results**

The results for different machines IHEP, CERN, FNAL, KNSU are given in Table. The following parameters have been calculated: $I_{th}$ is the threshold sensitivity of the detectors (the number of particles in the accelerator causing the appearance of a signal, equal to the device noise), $T$ is the wire heating temperature, $I_T/I_0$ is the relative values for the heat emission, as well as relative changes of the emittance $AE/E$, momentum $AP/P$ and beam losses $\Delta L/L$ as a result of scanning.

In the majority of cases the TV camera with LI-450 vidicon is capable of detecting the beam of high intensity. SIT guarantees the detection of separate bunches in the machine. ISIT allows one to control low intensity beams. For instance, in the case of the CERN antiproton beam a scanning device with detecting apparatus based on ISIT may be an alternative to the known techniques [10]. In this case the relative increase of the emittance will be not more than 3% the statistics measurement accuracy will be of about several percent.

<table>
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<th>Beam</th>
<th>$\gamma$</th>
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<th>$AP/P$</th>
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Notes: CERN AC — G81(Fe) wire, other machines — a carbon wire; KNSU — wire speed 100 m/s, for other machines — 4.3 m/s; CERN AC — wire diameter 10 \(\mu\)m, other machine — 25 \(\mu\)m.

**References**