IL NUOVO CIMENTO Vol. 34 C, N. 4 Luglio-Agosto 2011
DOI 10.1393/ncc/i2011-10935-5

Colloquia: Channeling 2010

Experimental investigation of optical transition radiation in amorphous quartz

A. R. Mkrtchyan(1)(*), A. H. Mkrtchyan(1), V. R. Kocharyan(1),
A. E. Movsisyan(1), A. H. Aslanian(1), Z. G. Amirkhanyan(1),
A. P. Potylitsyn(2), A. S. Gogoliev(2) and V. Bespalov(2)

(1) *Institute of Applied Problems of Physics - Nersessian Str. 25, 375014 Yerevan, Armenia*
(2) *Tomsk Polytechnic University - Lenin Ave. 30, 634050 Tomsk, Russia*

(ricevuto il 22 Dicembre 2010; pubblicato online il 22 Agosto 2011)

Summary. — Optical transition radiation (OTR) in amorphous quartz is investigated experimentally for electrons with energies 7.5 MeV. It is shown that the Cherenkov radiation and OTR can be separated at specific conditions. The linear polarization of OTR is investigated and it is shown that the polarization is radial. The results of measurements for the spectral distribution of OTR have shown the maximum intensity of radiation at the wavelengths in the range 320–500 nm.

PACS `41.60.Dk` – Transition radiation.

1. – Introduction

For the modern accelerator physics the problem of beam diagnostics is highly important, since not only the information on the beam size and position is required, but it is also necessary to control the beam shape and its angular divergence [1-6]. One of the most common approaches to solve these problems is based on the detection of optical transition radiation (OTR) from charged particles. OTR from relativistic electrons has been previously investigated experimentally in metals and dielectric materials. In these experiments the radiation was detected in the backward geometry with respect to the direction of the electron motion. Preliminary experimental results for OTR from charged particles in the forward geometry are provided in [7]. For the first time OTR phenomena on amorphous quartz with inhomogeneous dielectric permittivity induced by the nonuniform energy losses of transmitted electrons have been observed. The polarization of OTR has been registered. In the present work OTR and Cherenkov radiation spectral distribution and polarization has been investigated in details for the amorphous quartz with inhomogeneous dielectric permittivity.

(*) E-mail: `malpic@sci.am`

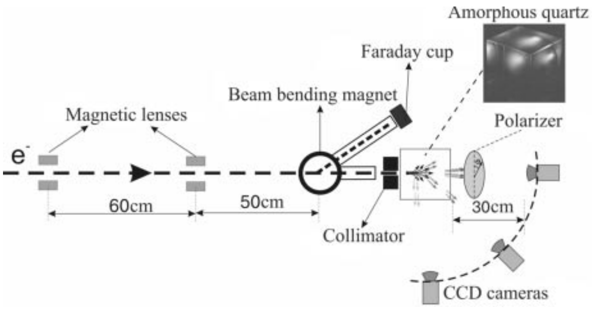

Fig. 1. – The experimental setup for studying OTR.

2. – Experiment

The results presented in this work have been obtained via the investigations carried out at the Yerevan Physics Institute microtron source for the electron energy 7.5 MeV, the beam diameter of 4 mm, the angular divergence of the order of 20 mrad, and the duration of macropulse of 2 μs. The experimental layout is presented in fig. 1.

The electron beam is formed by means of magnetic lenses, and after that the beam passes through the lead collimator (with the diameter 4 mm and the length 5 cm) and is scattered on the specimen. The direction of the beam propagation is controlled by using the beam-bending magnet located before the collimator. The beam current was measured by means of the Faraday cup. The intensity of OTR was measured using the FEU-85 type photomultiplier tubes (PMT) and the frequency distribution was obtained using the filters placed before FEU-85 PMT. The beam polarization was measured using the set of special lenses located in front of the photographic camera. An opportunity of camera operation in the accumulation mode was provided. As the specimen we have used amorphous quartz with 3 cm long edge and amorphous quartz with 1.5 mm thick plate of 17 mm in diameter.

In the transverse direction the dimension of the prism provides the condition of total internal reflection ($\theta_{\mathrm{Cher}} \approx 43°$) for the formed Cherenkov radiation ($\theta_{\mathrm{Cher}} \approx 46.8°$) in the specimen, whereby the conditions are produced for the detection and separation of Cherenkov radiation from OTR ($\theta_{Tr} \approx \gamma^{-1} \approx 3.6°$) (see fig. 2) and detection of OTR in the forward direction without the beam bending magnet and other devices. In fig. 3 we have presented the light images of Cherenkov and optical transition radiations observed at different angles (θ) with respect to the direction of the electron propagation.

Based on Monte Carlo method for amorphous quartz (30 mm thick) the distribution of energy losses of electrons along the beam trajectory has been calculated. In fig. 4 (a) and (b) the results of Monte Carlo calculations are given. As is seen from figs. 3 (a,e) and 4, the experimental and numerical results are in good agreement.

As is seen from the above results, the selected size of specimen provides complete absorption of electrons and, naturally, an opportunity of photon detection in the straight-forward geometry in the absence of the beam bending magnet. The appropriate features were obtained for the thin specimen when the end plane of specimen was perpendicular to the direction of the electron beam propagation. The experimental results show that in case of 1.5 mm thick amorphous quartz the peak of the transition radiation intensity corresponds to the wavelengths range 320–500 nm. The results of the OTR detection

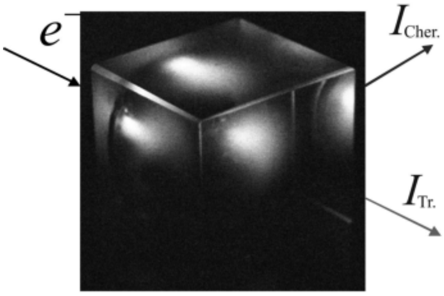

Fig. 2. – Formation of Cherenkov and optical transition radiation.

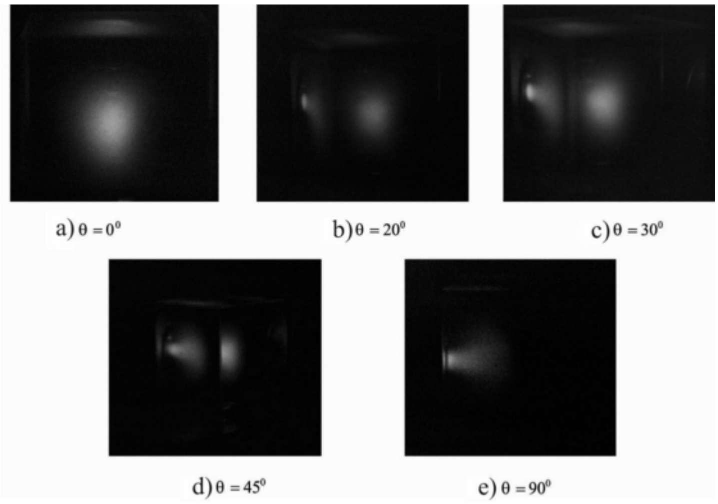

Fig. 3. – The images of Cherenkov and optical transition radiation at different observation angles (θ) with regard to the direction of electron flight in amorphous quartz.

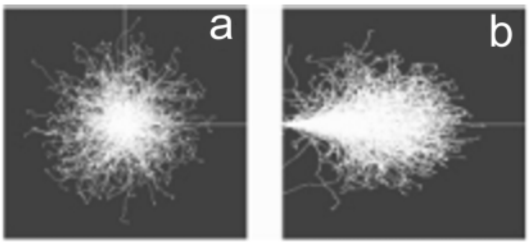

Fig. 4. – Distribution of the trajectory of electrons in length (a) and crosswise (b) directions of the motion of electrons.

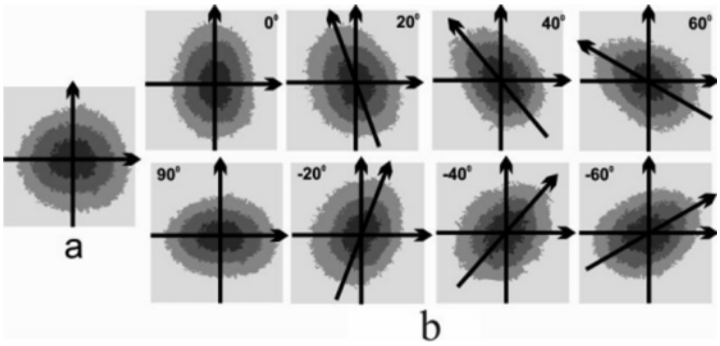

Fig. 5. – a) $\theta_{Tr} \approx \gamma^{-1}$, b) with indication of angular orientation of the polarizer to OTR beam.

in the geometry $\theta_{Tr} \approx \gamma^{-1}$ (fig. 5 (a)), in the presence of the polarizer in front of the detector, are shown in fig. 5 (b). As is seen from these figures, the polarization vector of OTR follows the polarizer's vector. Thus, both the angular distribution and the existence of the polarization of radiation are the facts in favor of OTR that is formed in the longitudinal direction $\varepsilon(z)$.

As is seen, the polarization degree is about 20–25% for the simple reason that along with 100 polarized transition radiation, the detector also recorded the unpolarized Cherenkov radiation emitted in casual trajectories of electrons stopping in amorphous medium. Taking into account the reduction of the contribution from Cherenkov radiation background, some experiments were conducted according to the previous scheme with the only difference that between the specimen and the polarizer a conical shape detail was placed. The results of experiments for 90° and 0° are shown in fig. 6 and it is seen here that due to the reduced Cherenkov radiation background the polarization of the optical transition radiation is manifested more explicitly.

3. – Conclusion

We have experimentally studied the features of OTR in amorphous quartz from electrons with energies 7.5 MeV. It is shown that for the chosen target material the Cherenkov radiation and OTR propagating at angles of the order γ^{-1} generated in the same target can be separated. The linear polarization of the OTR is investigated and it is shown that

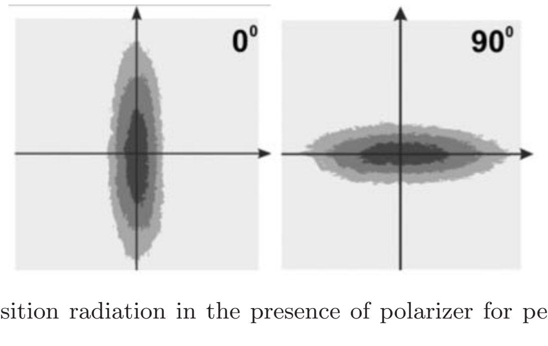

Fig. 6. – Optical transition radiation in the presence of polarizer for perpendicular vectors of the polarizer.

the polarization is radial. The results of the measurements for the spectral distribution of OTR show that the maximum of the radiation intensity corresponds to the wavelengths in the range 320–500 nm.

REFERENCES

[1] Rule D., Fiorito R. and Kimura W., *Proceedings of the 7th Beam Instrumentation Workshop Argonne IL*, *AIP Conf. Proc.*, **390** (1997).
[2] Ter-Mikaelian M., *High-Energy Electromagnetic Processes in Condensed Media* (Wiley/ Interscience, New York) 1972.
[3] Potylitsyn A. and Potylitsyn N., ArXiv:physics/0002034 (2000).
[4] Potylitsyn A., ArXiv:physics/0408024 (2008).
[5] Garibian G. and Yang S., *Transition Radiation* (AS Arm. SSR Press, Yerevan) 1983.
[6] Ginzburg V. and Tsitovich V., *Transition Radiation and Transition Scattering* (SSSR Press, Moscow) 1984.
[7] Mkrtchyan A. *et al.*, *J. Contemp. Phys. (Arm. Acad. Sci.)*, **4** (2010) 181.