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STUDY OF PULSED CATHODOLUMINESCENCE OF CALCIUM, BARIUM, LITHIUM, AND MAGNESIUM FLUORIDES

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INTRODUCTION

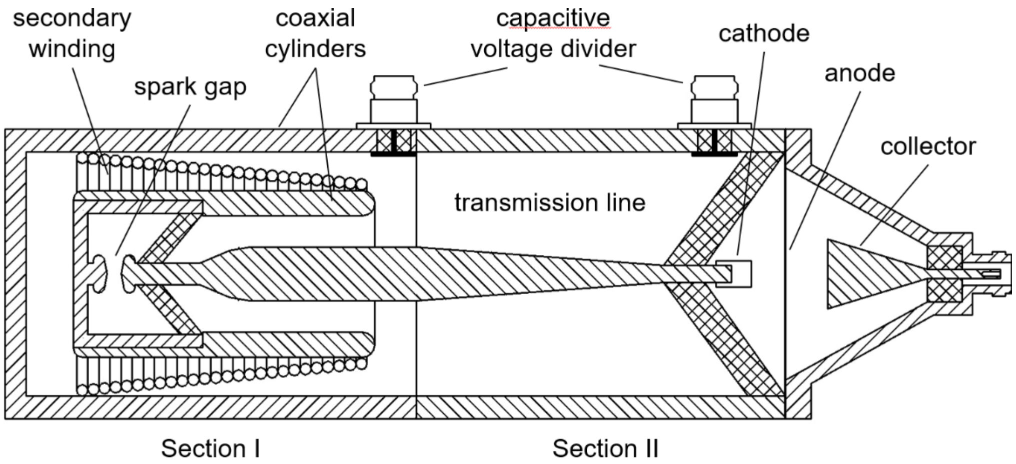
There are various gauges and methods of measuring the energy of runaway electrons and their spatial distribution [1-3]. One of the promising devices for detecting runaway electron beams are the optical systems using, according to [4, 5], Cherenkov radiation. Radiation detectors in these systems are diamond crystals the luminescence of which is transmitted through a lightguide to a photomultiplier tube (PMT) placed outside of the working chamber. According to L. Jakubowski *et al*. [4, 5], Cherenkov radiation is recorded by these detectors; however, no optical radiation spectra were presented in works of these authors. The radiation detector was calibrated only in [5], and the radiation spectrum was presented that did not correspond to the Cherenkov radiation spectrum in diamond.

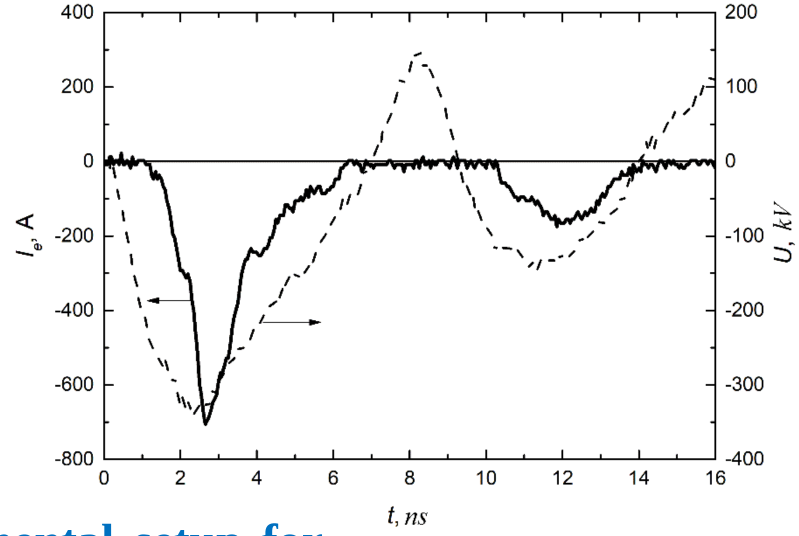
Studies of the luminescence of specimens made of natural and artificial diamonds irradiated by electron beams with energies of several ten to several hundred kiloelectron volts using standard spectrometers in the range of 200–1000 nm showed that only pulsed cathodoluminescence (PCL) bands were recorded [6]. UV part of Cherenkov radiation spectrum in diamond irradiated by runaway electrons with energies up to 200 keV was recorded for the first time in [7] using a monochromator and a high-sensitive PMT. To record Cherenkov radiation using a standard spectrometer, it was necessary to increase the electron energy [8, 9]. However, data on the Cherenkov radiation spectra in different crystals are currently scarce.

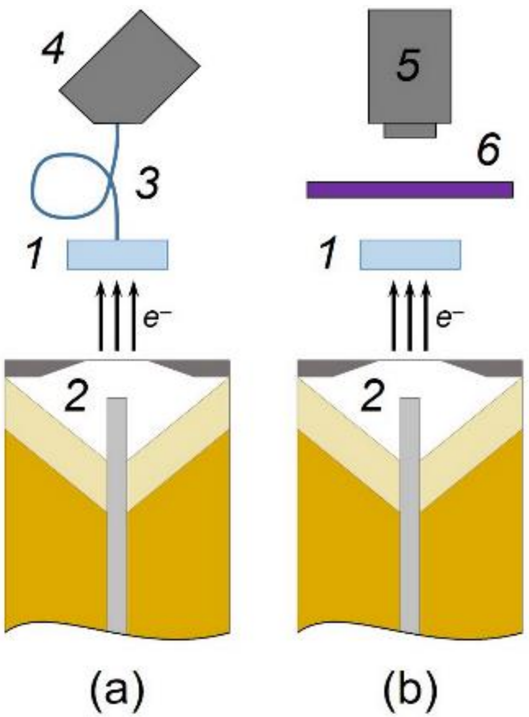
The aim of the work is investigation of the PCL and Cherenkov radiation spectra of CaF_2, BaF_2, LiF, LiF–W, and MgF_2 crystals irradiated by electron beams to determine the spectral regions with the most intensive bands and crystals with the highest Cherenkov radiation intensity as well as to measure the radiation pulse duration.

Unlike [10], the electron energy was increased to 350 keV, and the beam current pulse duration was increased to 1.3 ns.

EXPERIMENTAL SETUP







Sketch of the experimental setup for (a) taking emission spectra and (b) measuring the amplitude-time characteristics of the radiation:

1 **– specimen (0.7–8 mm thick),**

2 **– vacuum diode,**

3 **– optical fiber,**

4 **– spectrometer,**

5 **– PD025 photodiode,**

6 **– optical filter UFS-1,**

Signals from the photodetector and the collector for measuring the beam current were recorded using a Keysight DSO–X6004A digital oscilloscope (6 GHz, 20 Sa/ns).

CaF_2 CRYSTAL

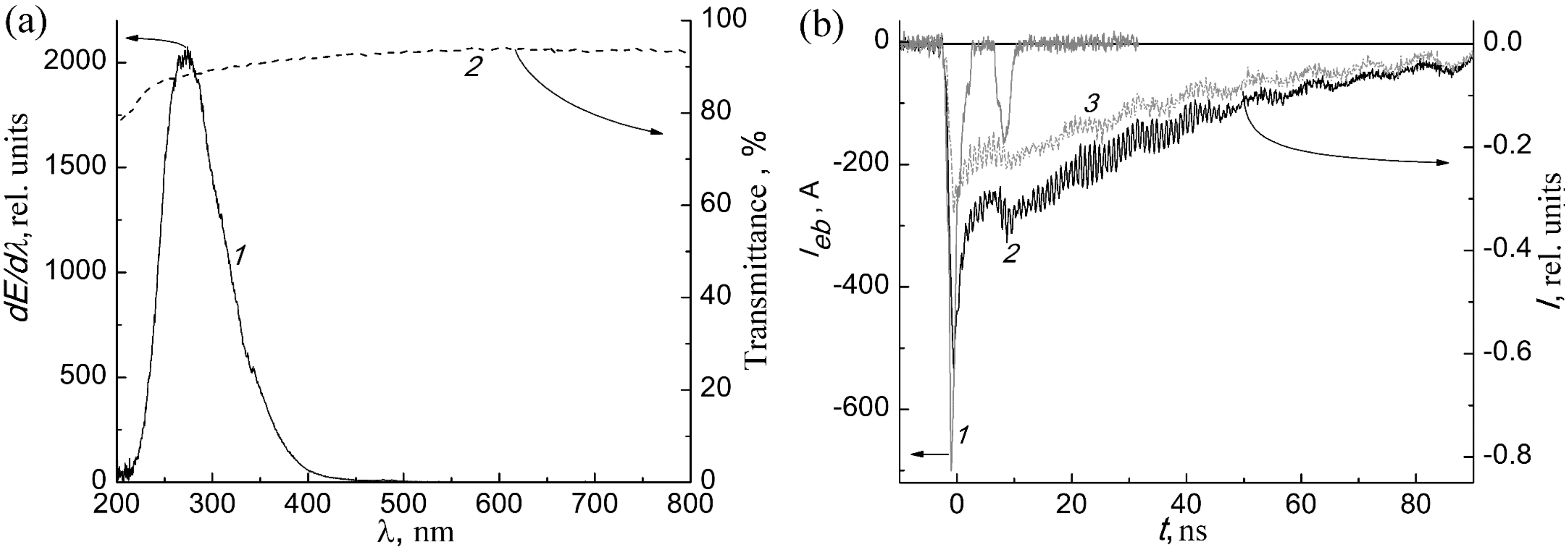


Fig. 1. Cathodoluminescence spectra of the CaF_2 crystal (curve 1) irradiated by the electron beams and transmission spectra (curve 2) (a). Pulse of the electron beam current I_{eb} (curve 1) and time history of radiation recorded with the Photek PD025 photodetector without (curve 2) and with the UFS-1 optical filter (curve 3) (b).

BaF_2–Ce CRYSTAL

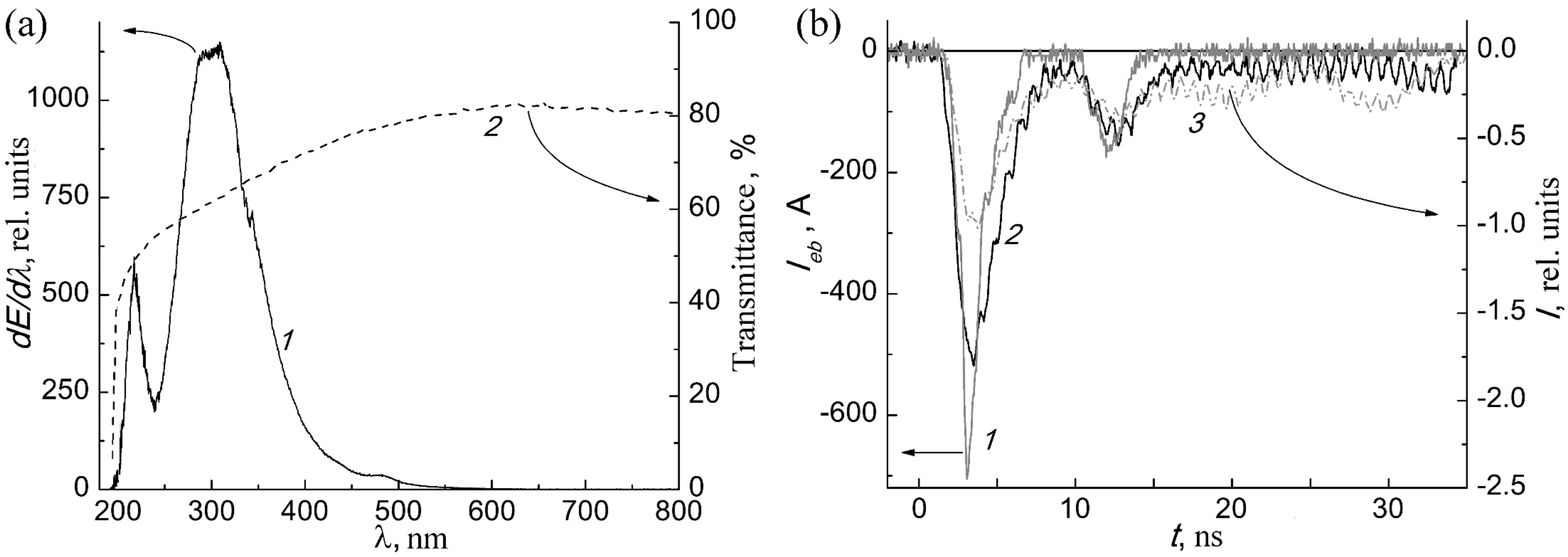


Fig. 2. Cathodoluminescence spectrum of the BaF_2–Ce crystal (curve 1) irradiated by electron beam and transmission spectrum (curve 2) (a). Pulse of the electron beam current I_{eb} (curve 1) and time history of radiation recorded with the Photek PD025 photodetector without (curve 2) and with the UFS-1 optical filter (curve 3) (b).

LiF CRYSTAL

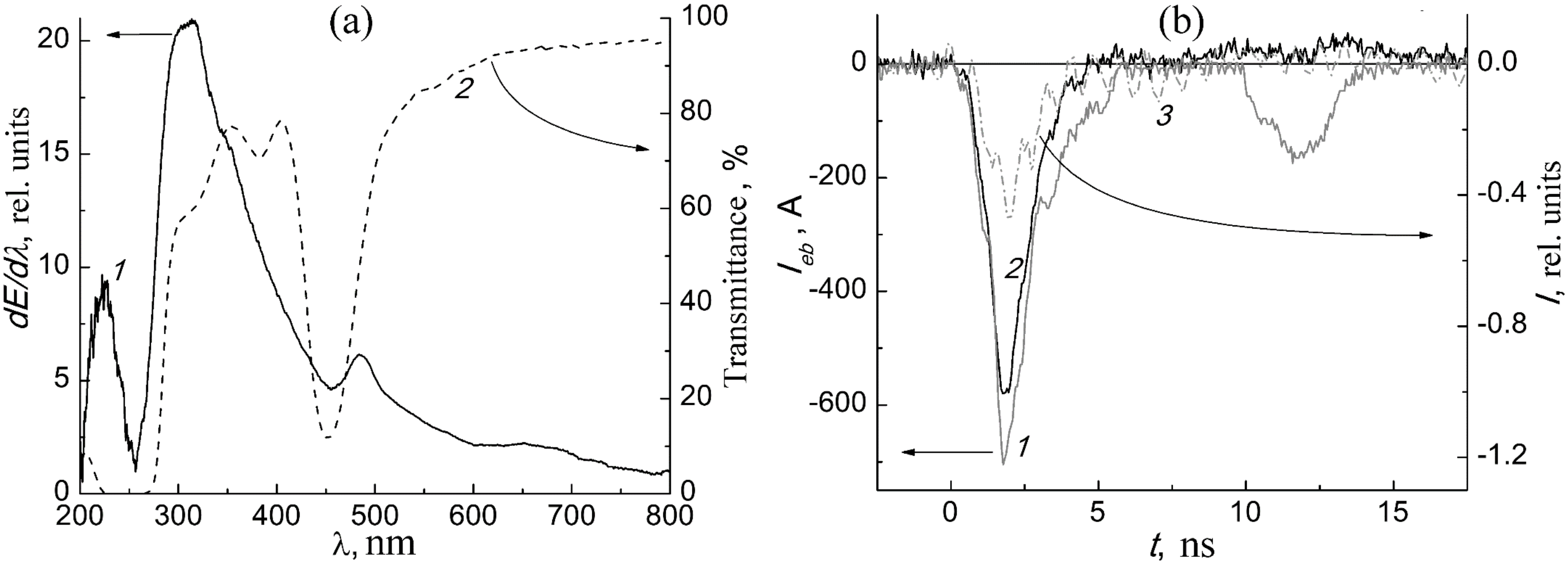


Fig. 3. Cathodoluminescence spectrum of the LiF crystal (curve 1) irradiated by the electron beam with accumulated radiative defects and transmission spectrum (curve 2) (a). Pulse of the electron beam current I_{eb} (curve 1) and time history of radiation recorded with the Photek PD025 photodetector without (curve 2) and with the UFS-1 optical filter (curve 3) (b).

LiF-W CRYSTAL

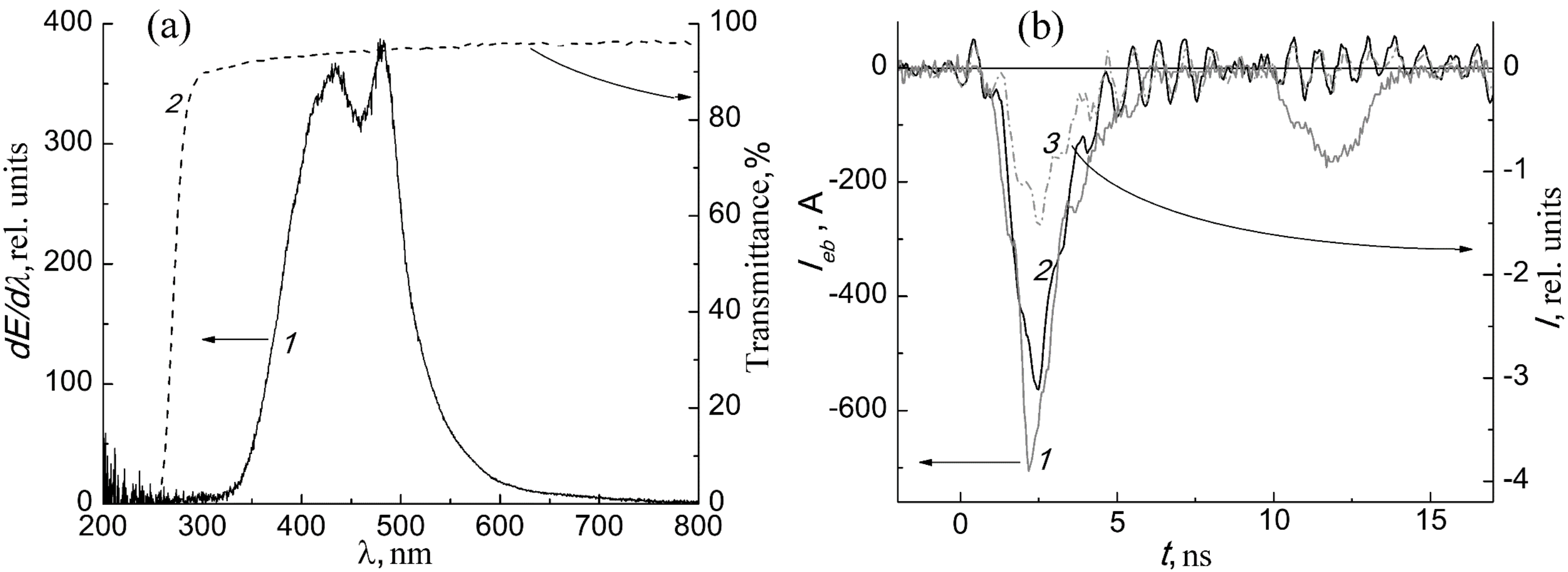


Fig. 4. Cathodoluminescence spectrum of the LiF–W crystal (curve 1) irradiated by electron beam and transmission spectrum (curve 2) (a). Pulse of the electron beam current I_{eb} (curve 1) and time history of radiation recorded with the Photek PD025 photodetector without (curve 2) and with the UFS-1 optical filter (curve 3) (b).

MgF_2 CRYSTAL

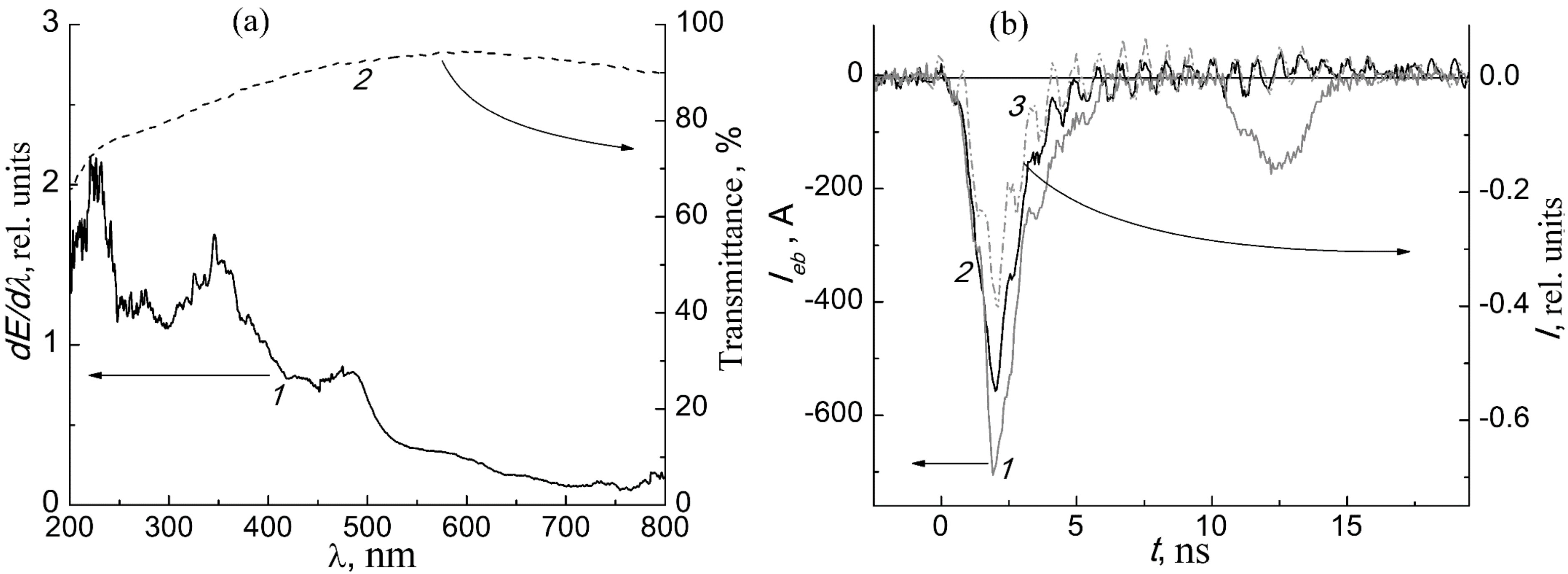


Fig. 5. Cathodoluminescence spectrum of the MgF_2 crystal (curve 1) irradiated by electron beam and transmission spectrum (curve 2) (a). Pulse of the electron beam current I_{eb} (curve 1) and time history of radiation recorded with the Photek PD025 photodetector without (curve 2) and with the UFS-1 optical filter (curve 3) (b).

Conclusion

The use of the MgF_2 crystals with low PCL intensity in the short-wavelength range of the spectrum irradiated by the electron beam with energy up to 350 keV has allowed us to record Cherenkov radiation. In addition, the MgF_2 crystal has high radiation stability caused by low efficiency of transformation of the primary hole centers into the stable ones. This allows one to use the MgF_2 crystal as a gauge of runaway electron beams. Other crystals investigated in the present work have intense exciton bands in the short-wavelength region of the spectrum or are nontransparent, as in the case of the LiF–W crystal. All this hinders recording of Cherenkov radiation.

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