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SYNCHROTRON RADIATION BEAMS DOSIMETRY BY TFD

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Synchrotron radiation beams produced in electron storage rings are excellent low energy X-ray sources. The peculiar characteristics of these beams (high power; low energy) require a very original dosimetry technique. In this paper the use of thin film dosimeters (TFD) is considered. Films of different colours (blue and green) were exposed to the LNF wiggler beam for calibration purposes. Examples of the use of these films for beam mapping and depth dose measurements are also shown.

1. Introduction

As already known, synchrotron radiation beams produced in electron storage rings are excellent low energy X-ray sources. The radiation emitted has a continuous spectrum characterized by a critical energy $\epsilon_c[\epsilon_c = E^3/R$ keV where E (GeV) is the energy of the electrons moving in a ring of radius R(m)]. The portion of the spectrum generally considered useful extends up to 5 or 6 times the critical energy. Using a special periodic magnetic field structure called a "wiggler", which forces the electrons to oscillate around their trajectories, it is possible to enhance and modify the energy spectrum. Monochromatic X-ray beams are obtained by using suitable monochromators.

Accurate dose measurements on synchrotron radiation beams are required for radiation protection purposes and in radiobiology, radiochemistry, etc. The dose measurement techniques most frequently used are not helpful in this case because of the high intensity and low energies of these beams.

A dosimeter suitable for such measurements must have a uniform sensitivity to X-rays of energy between a few keV and some ten keV into a very large dose range. A linear response is also desirable in this range, but not strictly necessary. In order to eliminate absorption problems the dosimeter should have walls of very small thickness. In fact, at these energies, a thickness equivalent to some ten centimetres of air is sufficient to reduce the beam intensity remarkably [1]. Of course, the dosimeter should also satisfy all the other requirements for this kind of instrument, such as reliability, fading, etc.

In our laboratory we have worked on the measurements of absorbed dose in materials of dosimetric interest exposed to synchrotron radiation beams. For this purpose we studied the response of some detectors (free air ionization chambers, TLD, thin cellophane films) which satisfy many of the above-mentioned characteristics. The results obtained by TLD have been presented in other papers [2,3]. This paper shows the results obtained using blue and green thin film dosimeter (TFD).

It should be noted that exposure to ionizing radiation bleaches the colour of films irreversibly and the absorbed dose can be evaluated by measurements of optical density. The mechanism of the bleaching effect has not been completely clarified yet although the use of blue cellophane films in radiation dosimetry has been known for a long time [4]. These films were also used around electron accelerators for beam maps and depth doses measurements [5]. Cellophanes of other colours are not so frequently used and there is very little information about them available in the literature.

The films must be handled with care in order to avoid finger-prints, creases, scratches, dirt and other alterations to the light attenuation. It is convenient to cut the film sample with one edge parallel to the striations in the cellophane and the other orthogonal to them. This makes it easy to scan along the striations at adjacent points on the cellophane and tends to make the readings more reproducible [5].

Due to their small thickness these films are suitable for absorbed dose measurements with low-energy high-intensity X-ray beams. Moreover, they are even useful for investigating radiation fields strongly variable from point to point.

2. Experimental results

We have used blue and green thin cellophane foils of commercial type, 15 and 30 μm thick, respectively. In order to read the change in dye density a He–Ne laser with a characteristic wavelength of 6328 Å has been used. This wavelength is the most suitable one to measure the change in optical transmission with the blue cellophane. The laser power was of 15 mW, but the light beam was filtrated with two Wratten filters. By a laser meter, EG-G model 460-1A, we were able to measure the laser power transmitted through the cellophanes.

The foils were exposed to the X-ray beam of the synchrotron radiation of the Adone wiggler channel ($\epsilon_c = 2.7$ keV). In order to study the response of the detectors versus the absorbed dose, various blue and green TFD were exposed at the same point for different periods. The effective spectrum of the radiation hitting the foils was calculated by computer taking into account the absorption of the berillium window (73 μm) of the channel and of about 55 cm of air interposed. The results of this calculation in terms of dose-rate in water per unit current in Adone are shown in fig. 1, where E indicates the value of the energy of the storage beam and I_w that of the wiggler supply current. The curve allows the evaluation of the doses received from the various TFD from the exposure period and the circulating current in Adone. The results of the measurements for the two sets of foils, green and blue, are shown in figs. 2 and 3, respectively. In these figures the optical density is plotted versus the absorbed dose in water. There are no substantial differences in the responses of the two sets of foils.

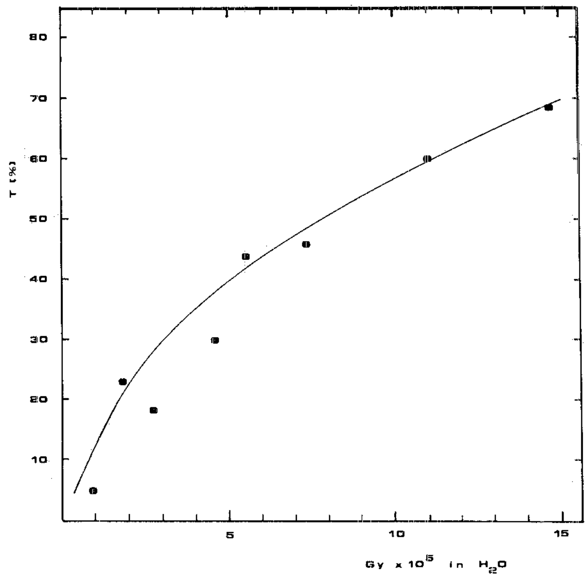

Fig. 2. Optical density vs. absorbed dose in water for green cellophane TFD.

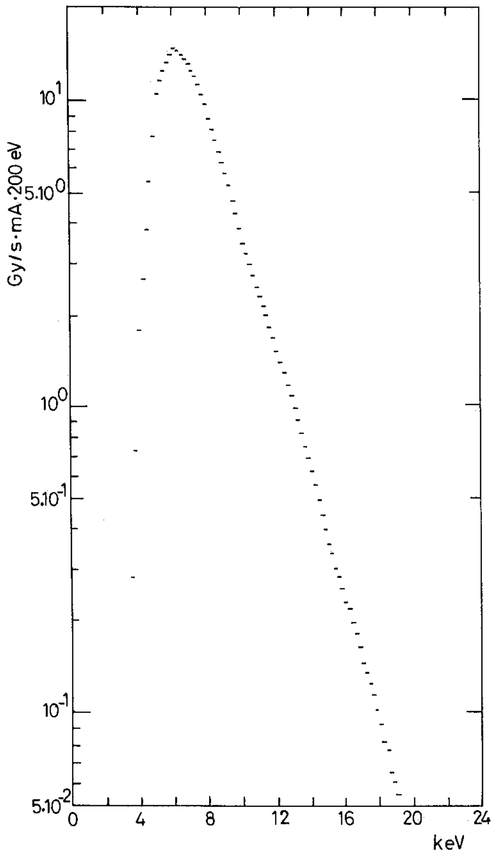

Fig. 1. Dose rate distribution per unit current stored in Adone vs. photon energy ($E = 1500$ MeV; $I_w = 4500$ A).

Blue and green cellophane foils were then successfully used to investigate the structure of the radiation synchrotron beam. As an example, two beam maps so obtained are shown in figs. 4 and 5; in each case the

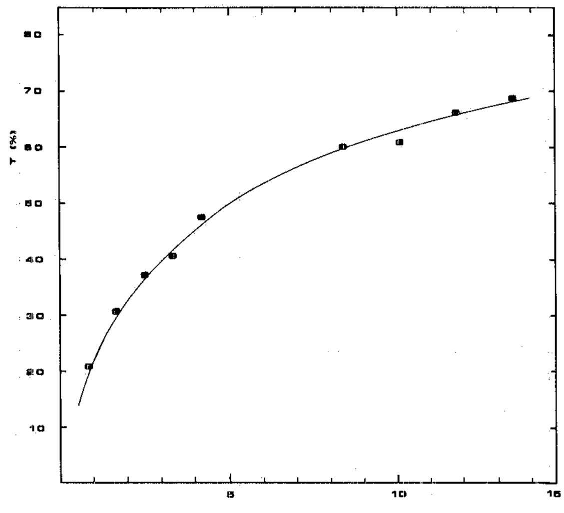

Fig. 3. Optical density vs. absorbed dose in water for blue cellophane TFD.

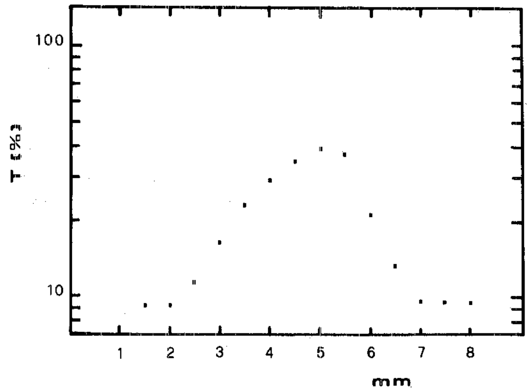

Fig. 4. Beam map of synchrotron radiation beam obtained by green cellophane TFD ($E = 1500$ MeV; $I_w = 4500$ A).

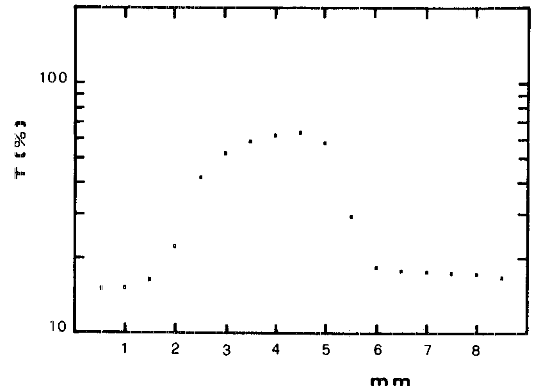

Fig. 5. Beam map of synchrotron radiation beam obtained by blue cellophane TFD ($E = 1500$ MeV; $I_w = 4500$ A).

values of main working parameters are reported in figure captions.

Using green cellophane films we studied the distribution of the adsorbed dose in a material approximately tissue equivalent (polyethylene) exposed to the synchrotron radiation beam of the wiggler channel in a point about 50 cm from the beryllium window. The spectrum of the synchrotron radiation on the polyethylene surface is shown in fig. 6. The experimental results and the transport calculations, already illustrated in a previous paper [1], are plotted in fig. 7. As can be seen, experimental results agree reasonably with the predicted calculations.

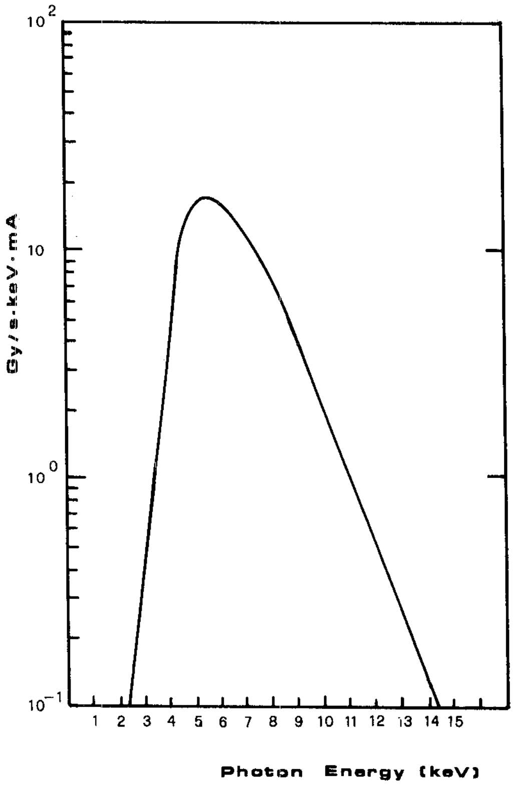

Fig. 6. Dose rate distribution per unit current stored in Adone vs. photon energy.

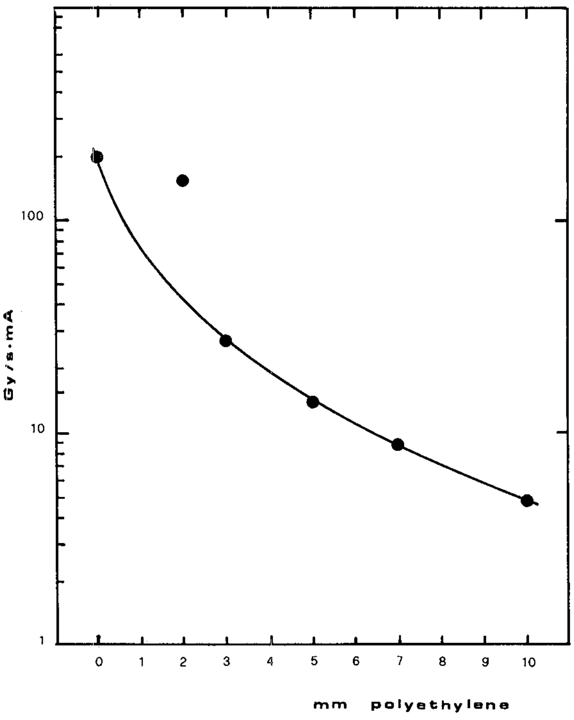

Fig. 7. Depth dose measurements and transport calculation.

3. Conclusions

In conclusion, the use of coloured cellophanes seems very interesting for various utilization in the range of the absorbed doses above 10^4 Gy especially in the case of low energy sources like synchrotron radiation beams, where the detector must be very thin to avoid important perturbations.

The use of TFD is also very useful for studying maps of high intensity radiation beams and depth dose distribution.

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