EVALUATION OF THE SPECTRAL DISTRIBUTION OF X-RAY BEAMS FROM MEASUREMENTS ON THE SCATTERED RADIATION

Ernesto Casnati[+] and Claudio Baraldi[++]

Istituto di Fisica dell'Università, Ferrara, Italy.

INTRODUCTION

The knowledge of photon or energy flux density distribution with respect to quantum energy is of certain importance when X-ray beams are produced by tubes supplied with voltages below 100 kV. The reason for this is threefold: 1) the interaction parameters show a high energy gradient below 100 keV, 2) secondary electrons produced by photons fall in an energy range which seems very effective in radiobiological damage (1), 3) beams of such kind are by far the largest source of irradiation for man (radiodiagnostic uses). In these cases, however, spectral distribution measurements present difficulties arising from the very high flux densities attained during the current pulse. Therefore, a number of contrivances have been proposed in order to make the nuclear spectrometers usable. The most important of these are: a) a very narrow beam collimation, b) a large distance between the focal spot and the detector, c) a very low current through X-ray tube.

PRINCIPLES

None of the above mentioned methods is free of criticism. For this reason a different approach was regarded as worthy of more detailed study. A very partial experiment on this spectrometry method is described by Greening (2). The principle of the method is based on the advantage which can be gained from the physical attenuation which the beam undergoes in its partial scattering over a thin sheet in order to solve the difficulty raised by high density fluxes. Therefore, a calculation procedure is required, suitable for the evaluation of the radiation incident on the scatterer from the instrumentally measured distribution. On the grounds of both theoretical and experimental considerations it may be inferred that as far as such kind of beam spectral analysis is concerned the most appropriate direction for measuring the scattered radiation involves crossing the beam axis at about $\pi/2$.

The evaluation of the true spectrum incident on the scatterer needs a procedure complicated on the one hand for the coexistence

---

+ I.N.F.N.,Sezione Sanità, Rome (Italy).
++ I.N.F.N.,Laboratori Nazionali, Legnaro (Italy).

of coherent and incoherent scattering and on the other hand for the presence of distortions caused by collateral physical effects. The exact solution with respect to the first problem can be obtained by measuring spectra of the same beam as scattered by two thin metallic sheets made of pure elements of different atomic number. An alternative procedure which appears equally satisfactory and much simpler both in theory and in experience, requires the measurement of the spectrum scattered by only one scatterer provided it is made of a pure element of a very low atomic number for which the interference between coherent and incoherent scattering is pratically avoided. The collateral effects are due partly to the response function of the detector and partly to distortions in the beam energy distribution caused by a number of unavoidable attenuators. There are no less than ten corrections to be considered.

Even if all of these effects are taken into account in the calculations, which is possible, the above mentioned spectrometry technique has a cost which is low and acceptable only for quantum energy below about 100 keV. In fact, apart from the resolution loss connected to the finite aperture of the beam which can be rendered negligible by a suitable choice of geometrical arrangement, that resolution loss coming from the broadening of the energy interval of the reconstructed discrete spectrum in comparison with the direct one should be pointed out. Indeed it is possible to show that the reconstruction necessarily involves the incoherent scattering which changes the energy interval breadth.

RESULTS

Two distributions are used in order to check the theory: a) the first one is the highly filtered spectrum produced by a Be window tube supplied with a high voltage of 60 kVp, an average current of 4 mA and filtered by an additional 0.5 mm Cu, b) the second one is the spectrum emitted by the same tube supplied with a high voltage of 30 kVp, an average current of 3 mA and filtered by the Be window 0.5 mm thick. While the first irradiation technique allows the comparison of the reconstructed spectrum with the direct one, the second technique requires a theoretical evaluation of the spectral distribution for comparison.

Being practically indistinguishable the results obtained from the measurement done with only one Be scatterer or from the two in which a Be and an Al scatterer are used respectively, no graphs comparing such results are given. In figure 1 the spectral distributions of the 60 kVp beam are drawn. The continuous line represents the spectrum measured on the direct beam at a suitably large focus to detector distance. The dotted line is the reconstructed spectrum. Besides the above mentioned corrections, in this example special atten-

tion must be paid to the difference in the dead time resulting from the two measurement conditions. The two spectra are normalized to the same area. Some differences are present and their amount is significant. This preliminary result, however, is still under investigation and a better understanding of such small discrepancies should be achieved very soon. In order to complete the evaluation of this X-ray spectrometry method a check is required at the lowest limit of the

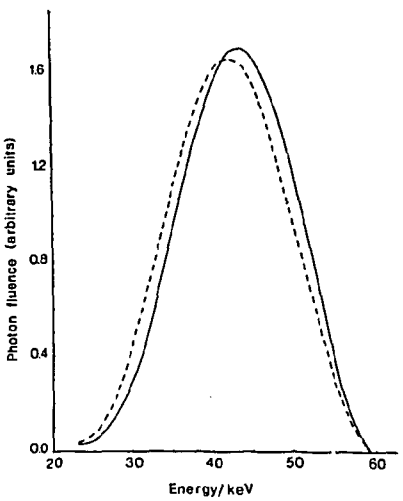

Fig.1: Distributions, twice smoothed, obtained at 60 kVp nominal high voltage: ——— primary spectrum, ----- reconstructed spectrum.

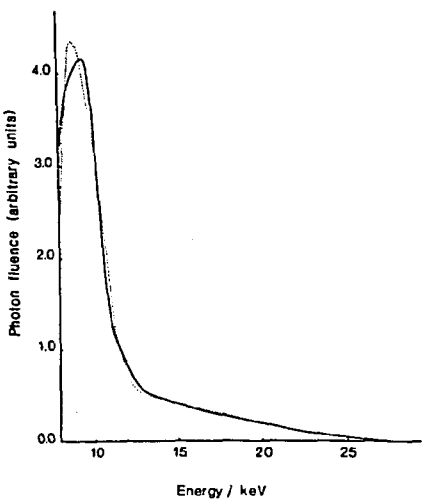

Fig.2: Distributions once smoothed, obtained at 30 kVp nominal high voltage: ——— calculated spectrum, ----- reconstructed spectrum.

pratical energy range. The second irradiation technique satisfies this requirement with its large, low energy interval. The very high flux density and the presence of very low quantum energies do not allow the measurement on the direct beam. The comparison is then possible only by calculation of the spectral distribution. This is achieved by means of the procedure described by Birch et al. (3) for the continuous spectrum and by means of the one worked out by Casnati et al. (4) for the characteristic lines. The experimental reconstructed distribution (dotted lene) is compared with the theoretical spectrum (continuous line) in figure 2. The last one clearly includes the con-

volution with the response function of the spectrometer distorted for the scattering dependent energy interval change. Normalization criterion is like the one used for 60 kVp spectra but applied to the continuous component alone. Comments on this result are quite similar to those relevant to figure 1.

CONCLUSION

On the ground of the results so far gained the scattered radiation spectrometry seems a promising technique for a better description of low energy X-ray beams as their interaction properties and their large diffusion would need.

REFERENCES

1. Paretzke, H.G. (1976): In: Proceed. 5th Symp. on Microdosimetry, p.41. Eds.: J. Booz, H.G. Ebert and B.G.R. Smith. EUR 5452 d-e-f.
2. Greening, J.R. (1972): In: Topics in Radiation Dosimetry, p. 262. Ed.: F.H. Attix. Academic Press, New York.
3. Birch, R. and Marshall, M. (1979): Phys. Med. Biol., 24, 505.
4. Casnati, E., Baraldi, C. and Galvani, F.: In preparation.