Mammographic dosimetry

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1. Introduction

Clinical mammography tubes use a combination of different anode materials (Mo, Rh) and filters (Mo, Rh, Pd). At present, few national standard laboratories are equipped with these x-ray tubes. On the other hand, similar radiation qualities can be produced using x-ray tubes with a W-anode. Following the EUROMET project No 526 [1], a set of 9 such x-ray qualities was set up at the BIPM.

2. Method

2.1 New radiation qualities

A new set of radiation qualities has been established at the BIPM using the low-energy x-ray facility. A combination of the W-anode with two filter materials (Mo, Rh) and different tube voltages in the clinical mammography range was used to implement these qualities.
The beam quality (HVL) and the air kerma determinations were performed with the low-energy x-ray standard (free-air chamber). The correction factors for the standard for these new qualities were determined by interpolation from the existing data for the CCRI reference qualities [2], which were calculated using spectral measurements performed previously with the NMi spectrometer.
The table shows the characteristics of the new radiation qualities.

Generating potential / kV	23	25	28	30	35	40	50	25	30
Additional filtration *	60 µm Mo							50 µm Rh	
HVL / mm Al	0.332	0.342	0.356	0.364	0.388	0.417	0.489	0.464	0.505
K_{air} / mGy s^{-1}	1.000 (2)								

* 0.423 mm of Be was added to all the qualities

Three transfer ionization chambers of type Radcal RC6M and Exradin A11TW are being calibrated periodically in these beams; the stability and the energy dependence are being studied. Repeat calibrations over 2 years show a standard deviation of 0.07 % and 0.10 % in the Mo and Rh qualities, respectively.

2.2 Measurement of spectra

New spectral measurements have been carried out using the Compton scattering method, with a scattering angle of 90°. The primary x-ray spectra were reconstructed from the resulting pulse height distribution using commercial software [3]. A commercial Compton spectrometer has been used for the measurements, consisting of a scattering chamber with lead walls, lead collimators and a lucite rod of circular cross section used as the scatterer (Fig. 1).
The measurements were performed with a low-energy germanium detector (LEGe) coupled to a multichannel analyser (MCA). The known energies of the x- and γ-rays emitted by radioactive sources of ^{125}I and ^{241}Am were used for the calibration of the MCA.

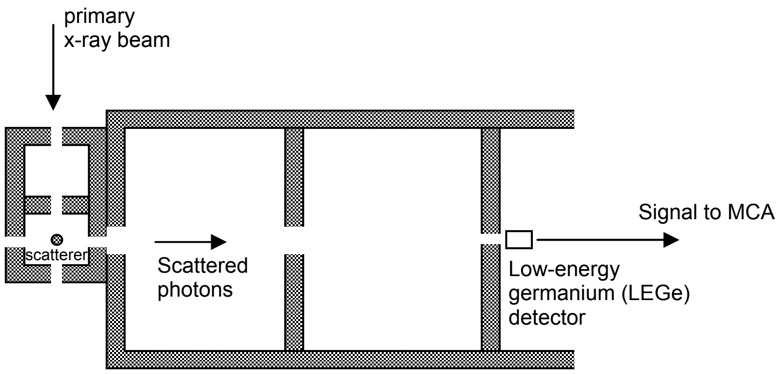

Fig. 1. Schematic diagram of the Compton spectrometer

2.3 Simulation of the spectra

Monte Carlo simulation of these spectra are being carried out using the PENELOPE code [4]. The x-ray tube (target, filters and collimation) has been simulated with the PENELOPE geometry code PENGEOM, as shown in Fig. 2.

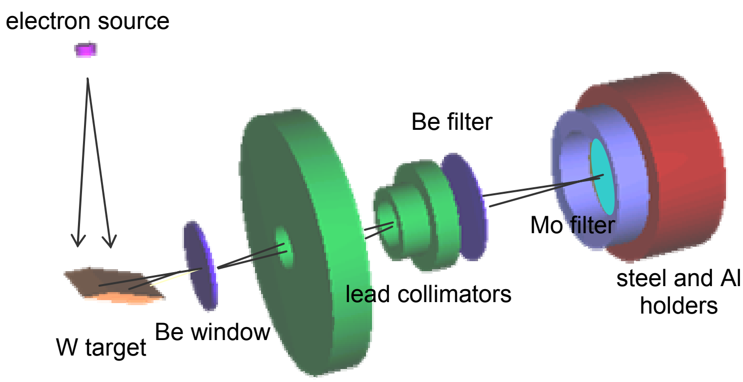

Fig. 2. Model of the x-ray tube, filters and collimators

This model was used to create a phase-space file of photons crossing the first lead collimator (plane at 5 cm from the centre of the target), including the energy, angle and position of each particle. The photon and electron cut-off energy was set to 1 keV. The following values were chosen for the electron transport parameters: C1 = C2 = 0.2, Wcc = Wcr = 1 keV. Interaction forcing for bremsstrahlung emission has been applied to the primary particles. This phase-space file was used as input for the transport of photons through the collimators and filters; the distribution of the photon number with energy was created at 50 cm from the centre of the target. For the second step, the photon cut-off energy was also set to 1 keV, while the electron transport cut-off was raised to the maximum photon energy value (that is, no electron transport).

3. Results

3.1 Spectral measurements

The measured spectra corresponding to 23 kV, 30 kV, 50 kV with the Mo filter and 30 kV with the Rh filter are shown in Fig. 3. The energy bins are 0.2 keV.

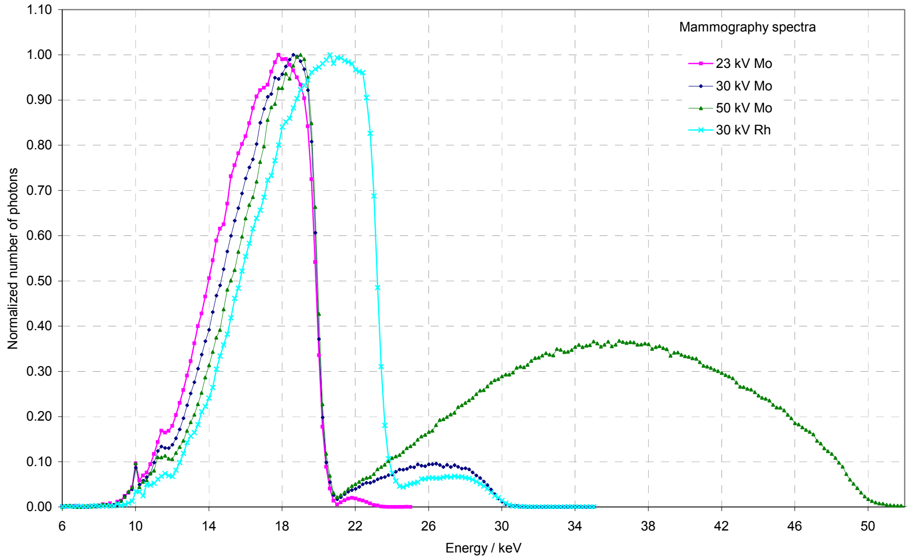

Fig. 3. Spectra measured with the Compton spectrometer

3.2 Spectral simulations

Figures 4 and 5 show the spectra for the 30 kV qualities with Mo and Rh filters, respectively, simulated with the PENELOPE code. Each spectrum is compared with that measured using the Compton spectrometer.

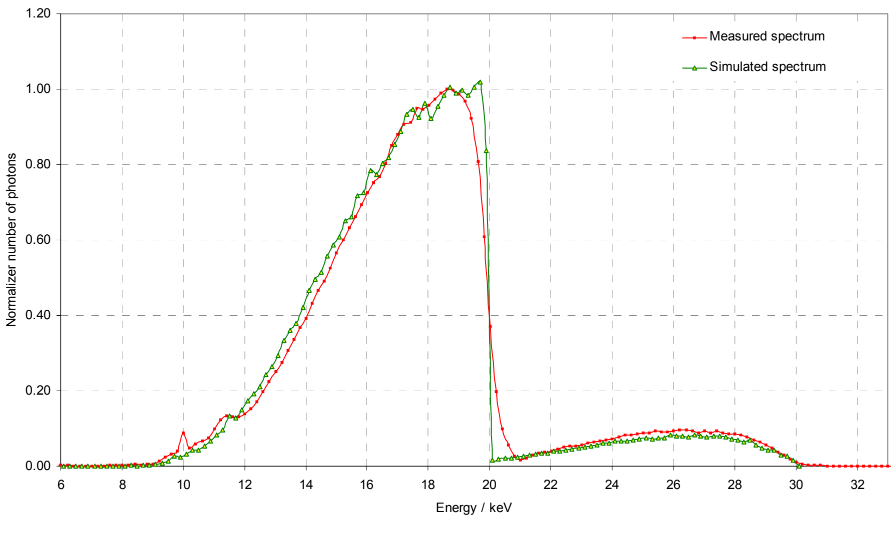

Fig. 4. Comparison of the simulated and measured spectra for the 30 kV, Mo filter quality

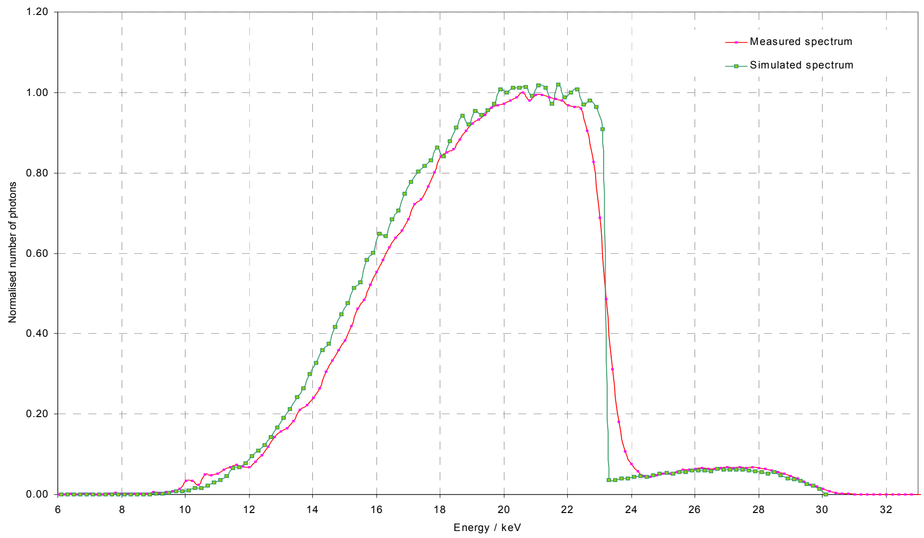

Fig. 5. Comparison of the simulated and measured spectra for the 30 kV, Rh filter quality

3.3 Spectra for the CCRI qualities

Spectra corresponding to the CCRI qualities were also measured and are presently being simulated with the same Monte Carlo code. Figure 6 shows the comparison of the spectrum for the 50 kV(a) quality (50 kV, 3.989 mm Al filter) measured recently with the Compton spectrometer with that measured previously by the NMi; the calculated spectrum is also plotted in the same graph. The energy bins are 0.2 keV and 0.5 keV for the measured and simulated spectra, respectively.

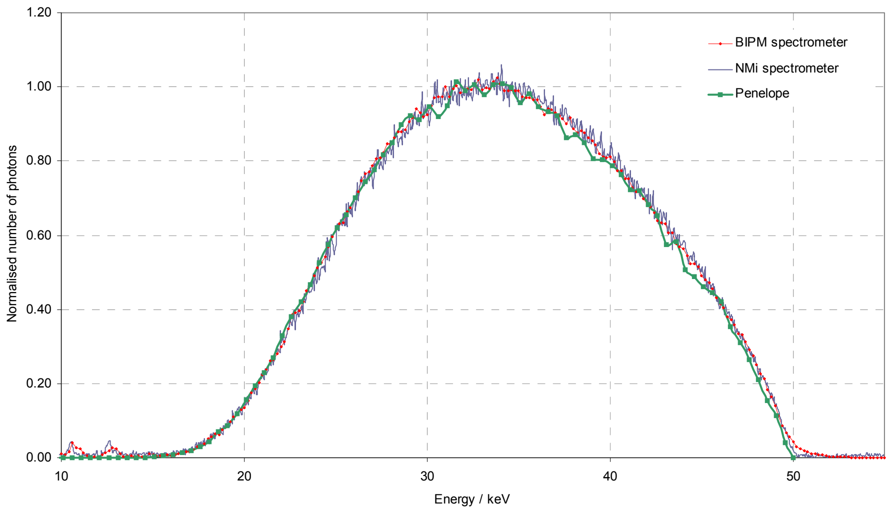

Fig. 6. Comparison of the simulated and measured spectra for the CCRI 50 kV(a) quality

4. Discussion

The measured and calculated spectra show good general agreement, particularly for the CCRI 50 kV(a) quality where the two measured curves are almost indistinguishables from the calculated curve (within the statistical noise).

Agreement for the 30 kV, Mo filter quality is a little better than that for the Rh filter quality, although calculations are still running to improve the statistical uncertainty for both. The energy broadening observed in the measured spectra at the absorption edge of the two filters may arise from the energy resolution of the Compton spectrometer.

5. References

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[2] BURNS, D.T., New correction factors for the BIPM free-air chamber standards. CCRI(I)/03-28.

[3] MATSCHEKO, G., RIBBERFORS, R., A generalised algorithm for spectral reconstruction in Compton spectroscopy with corrections for coherent scattering, *Phys. Med. Biol*. **34** (1989) 835-841.

[4] SALVAT, F., FERNANDEZ-VAREA, J.M., ACOSTA, E., SEMPAU, J., PENELOPE – A Code System for Monte Carlo Simulation of Electron and Photon Transport, NEA/NSC/DOC(2001)19 (ISBN 92-64-18475-9).