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Evaluation of energy distribution of quasi-monochromatic x-ray beams for sources with extremely high instantaneous flux using k-edge subtraction technique

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The characterization of novel x-ray sources includes the measurement of the photon flux and the energy distribution of the beam produced.
The aim of BEATS2 experiment at INFN-LNF is the study of medical applications of an x-ray source based on Thomson relativistic backscattering. This source is expected to produce pulsed quasi-monochromatic x-ray beam with an instantaneous flux of 10^20 ph/s in pulses 10 ps long and with an average energy of 20 keV.
A direct measurement of energy distribution of this beam with traditional detectors, such as HPGe, CZT or CdTe, is very difficult because of the extremely high photon flux. For this reason we have planned to use a technique based on beam filtration using k-edge absorbing foils in the energy range of interest (16-22 keV).
The measurement system is made of a free-air ionization chamber, a filter-wheel and a silicon PIN photodiode. The ionization chamber is used as beam monitor, in order to check the shot-to-shot repeatability. The filter-wheel is equipped with foils of Al, Mo, Nb and Zr. The thickness of each filter is chosen in such a way that the attenuation of photon with energy lower than the k-edge is the same for all materials. Thus the difference of the signals induced in the silicon photodiode by the beam attenuated with two different filters is related to the number of photons in the energy band ranging between the k-edges. By knowing the response function of photodiode is possible to reconstruct the energy distribution of the unfiltered beam from the subtraction of photocurrents induced by filtered beam.
The technique was tested using an x-ray tube with a tungsten anode at 22 kVp, filtered with 3.1 mm of Al providing an x-ray spectrum with an energy distribution similar to that expected from Thomson source.
In order to verify the proper selection of the filters thicknesses, the spectra transmitted by foils of Al (1.30mm), Mo (98 microns), Nb (125 microns) and Zr (175 microns), having k-edge energies at 20 keV, 19 keV and 18 keV respectively, were acquired with an HPGe detector.
Then the method has been tested by measuring the photocurrent induced in the PIN diode by the beam transmitted by the filters. The comparison between the results obtained analyzing the full measured spectra and those of the k-edge subtraction technique showed good agreement, confirming the goodness of the method.

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