Absolute calibration of photodetectors using a cryogenic electrical substitution radiometer

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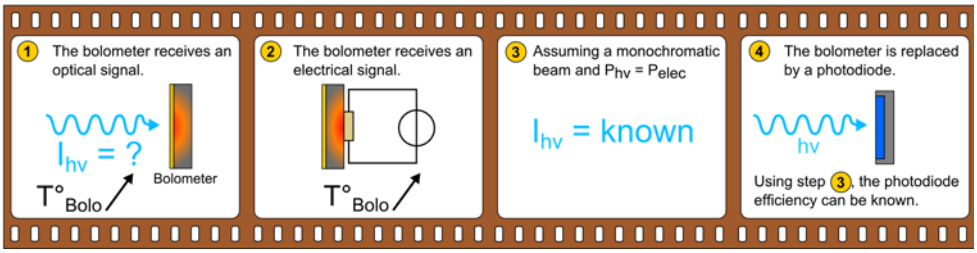
Absolute efficiency calibration of X-ray detectors is essential for applications in metrology and accurate quantitative analysis. Such a calibration can be provided by an electrical substitution cryogenic radiometer (or bolometer): this technique is well established by national metrology institutes, particularly in the area of visible radiation. It can also be applied to X-rays and is particularly well adapted to high photon fluxes delivered by synchrotron facilities like SOLEIL.

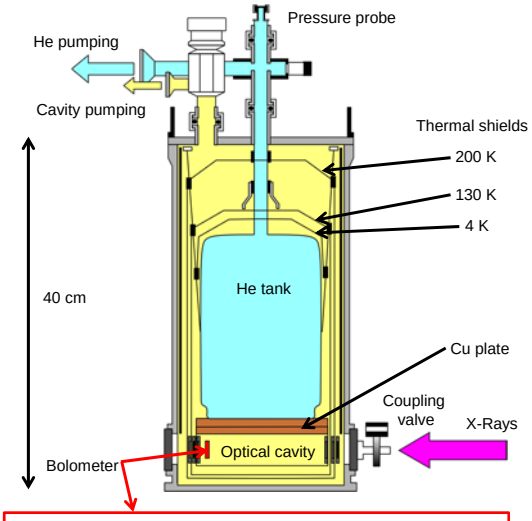
Bolometer and electrical substitution principle

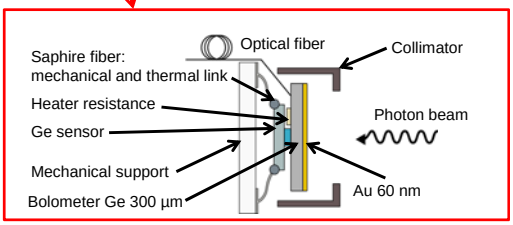
The bolometer, invented in 1878 by Samuel Pierpont Langley, is based on the measurement of the temperature increase induced in a target by the interaction of an electromagnetic radiation.
Since the temperature increase due to X-rays is very low, the detector is operated at cryogenic temperature (liquid helium).



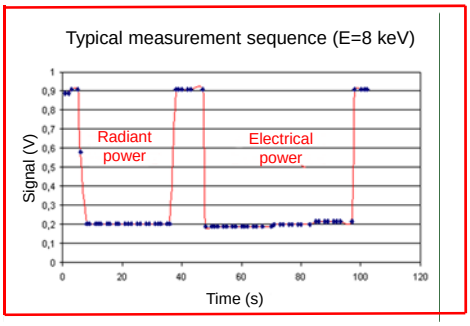
The electrical substitution is based on the assumption that the bolometer behaves in the same way either for an optical or an electrical signal. It allows photodetectors to be calibrated using the comparison procedure shown in the above figure: the radiant power incident on the absorber is compared with the electrical power required to heat the absorber to the same temperature.

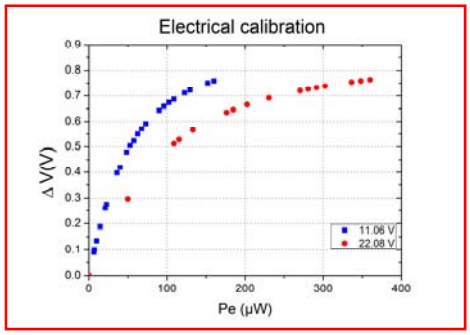
BOLUX: a specialized bolometer for X-rays

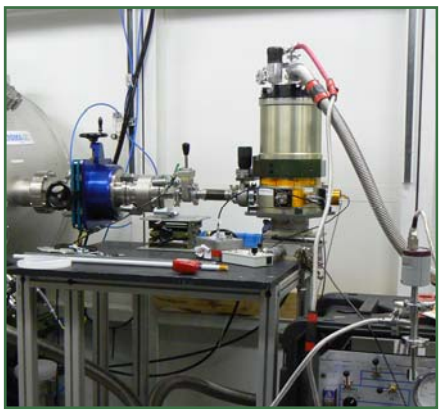




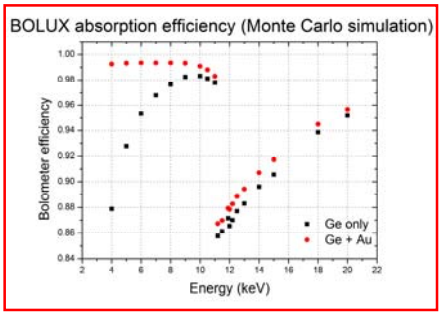
The BOLUX setup







The BOLUX experiment at SOLEIL

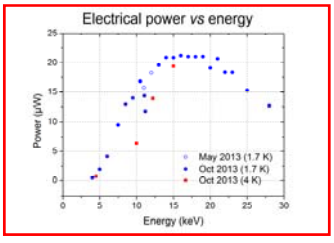


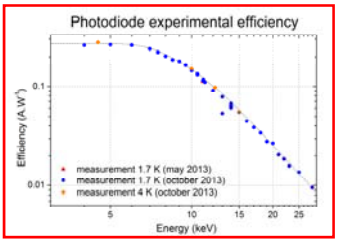
Efficiency calibration of a photodiode from 4 to 28 keV

Two datasets obtained with incident photon flux measured on a 2 x 2 mm² area.
(SOLEIL METROLOGY beamline / Hard X-rays branch):

- 1.7 K (with He pumping),
- 4 K (no He pumping).

The 4 K results allow the radiometer to be used without He pumping → **larger autonomy.**
The absolute efficiency plot shows a good agreement between the two datasets.
Typical relative combined uncertainty: 1-2 %.





Work in progress

- Voltage readout made by a multi-source analyser.
- Automatisation of the data acquisition for the Metrology beamline.

Next step: Calibration in the low energy range on the X-UV branch at the Metrology beamline (30 eV to 1.8 keV).

Acknowledgment

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