Edge-on illumination photon-counting for medical imaging

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X-ray Computed Tomography

Computed Tomography (CT) is a diagnostic technique that allows to see the inner structure of an object, exploiting the position dependent absorption of the incoming X-ray spectrum. It combines the familiar 2D radiography by means of a reconstruction algorithm to reconstruct a 3D image of the analyzed sample.
The basic CT scan setup includes:

- an X-ray source, usually an X-ray tube emitting photons with a continuous energy spectrum;
- a sample holder, which allows both to move the sample in the space and to rotate it;
- a pixel detector, to collect the photons in 2D.

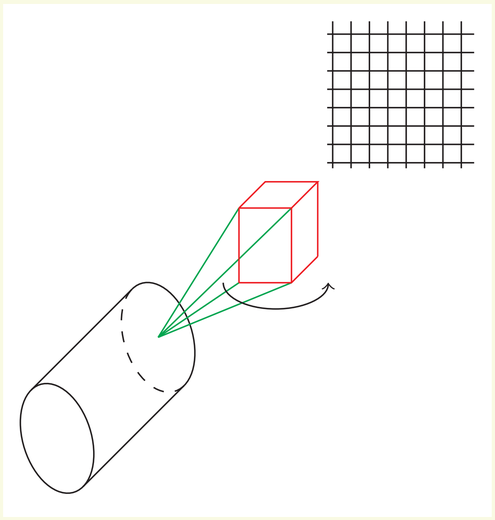


Fig. 1: From the left to the right: the X-ray source, the analyzed sample (rotating) and the pixel detector.

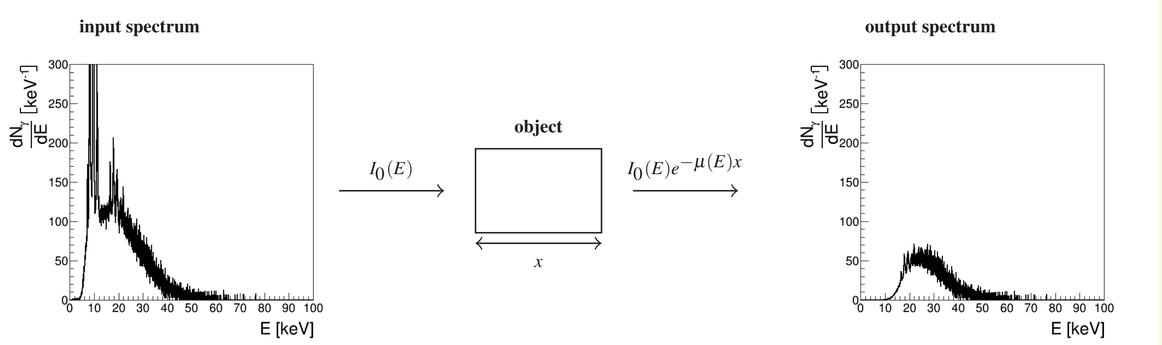


Fig. 2: Left: energy spectrum emitted from the source.
Right: energy spectrum after transmission through an Al layer.

The detector

In the present setup a Timepix chip based assembly is used; its main features are summarized below.

- semiconductor (Si) sensor, 500 μm thick;
- 256 x 256 square pixels (55 μm side);
- one energy threshold available;
- readout ASIC distinct from the sensor (hybrid detector).

An important feature is the possibility to work in three operational modes:

- photon counting;
- Time over Threshold (ToT);
- Time of Arrival (ToA).

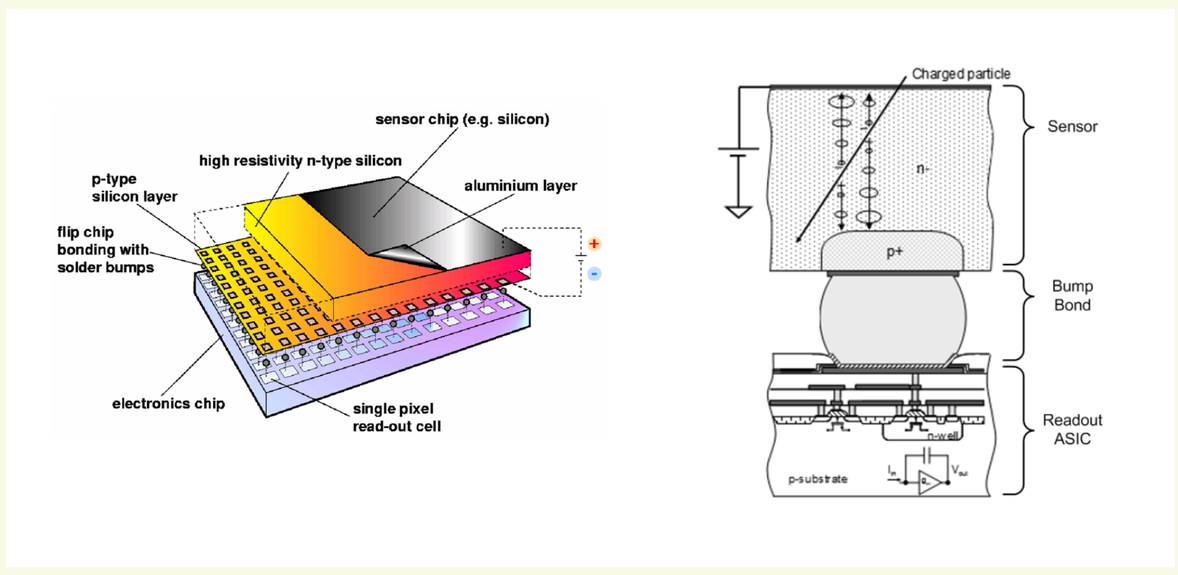


Fig. 3: Scheme of the detector [1] [2].

Two different geometries can be used:

- face-on: the matrix is perpendicular to the photon beam;
- edge-on: the detector is turned by 90°.

Spectral CT

An improvement of conventional CT is represented by spectral CT, in which an energy sensitive detector is used to deduce, from the photon energy, the material content of the sample. As a consequence:

- different images can be obtained with different constrasts between the materials inside the object;
- the artifacts due to the non-monochromaticity of the beam are reduced.

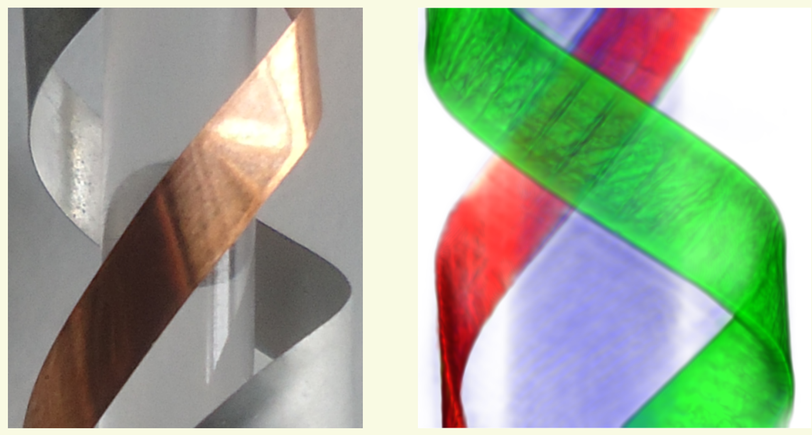
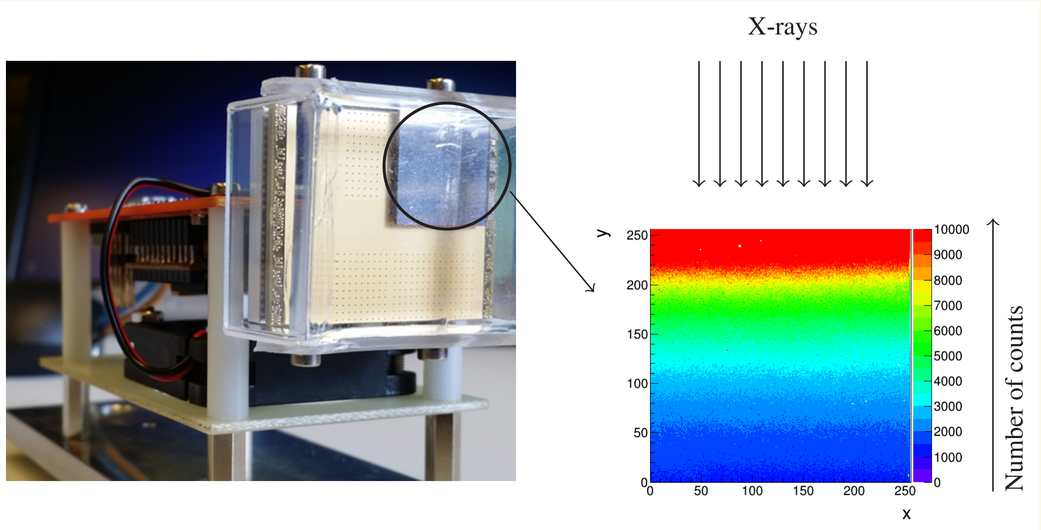


Fig. 4: Picture and CT reconstruction of two slabs of different materials wrapped around a plastic frame [3].

Edge-on geometry



Advantages with respect to the face-on geometry:

- much greater efficiency (the photons absorption efficiency is exponential with the thickness);
- energy discrimination: on average, the higher the photon energy, the longer the path of the photons inside the detector.

Future work

- Characterize the detector response
- Understand how energy is deposited in the detector (PE, Compton, ...)
- Understand how to read the information about the different energies in the different lines..
- .. with the final aim of doing a spectral CT
- Operate two detectors face-to-face
- Improve the circuitry (as well as the geometry) to do optimized X-ray detection for spectral CT purposes

Acknowledgments

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Bibliography

[1] Winnie Wong, A Hybrid Pixel Detector ASIC with Energy Binning for Real-Time, Spectroscopic Dose Measurements, PhD thesis, Mid Sweden University, 2012
[2] Xavier Llopart Cudié, Design and Characterization of 64K Pixels Chips Working in Single Photon Processing Mode, PhD thesis, Mid Sweden University, 2007
[3] E. Jr. Schioppa, J. Uher and J. Visser, "Construction and test of an X-ray CT setup for material resolved 3D imaging with Medipix based detectors", 2012