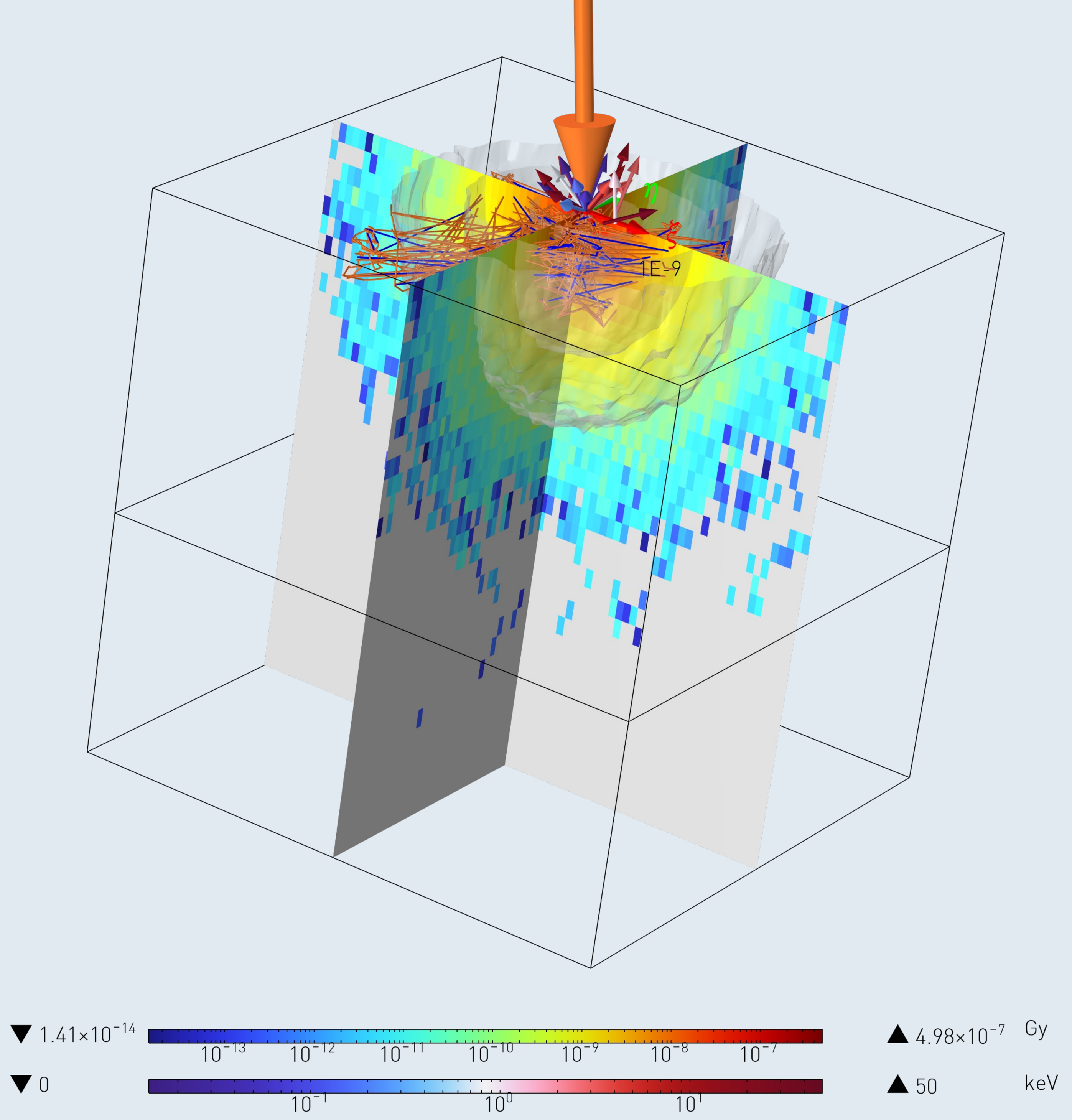

Radiation Transport in Solid X-Ray Targets

Simulate particle and energy transport in a solid X-ray target exposed to an electron beam using a Monte Carlo model. Obtain dosimetry quantities to assess photon emission, heat dissipation, and efficiency.

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Introduction

X-rays represent high-energy electromagnetic radiation capable to penetrate solid matter and are therefore widely used in medical diagnostics and material testing. In this context, they are produced using electron tubes through X-ray photon emission from the target material of the anode exposed to an electron beam with energies of $10^1 \ldots 10^2$ keV. Photons are produced by atomic interactions of electrons (bremsstrahlung emission) and radiative transitions (characteristic X-rays) of excited atoms. Only a small fraction of the electron energy is transformed to photon energy with the remainder deposited in the target material resulting in significant thermo-mechanical loads and leading to various strategies to cope with them, for example using rotating anodes (Figure 1). Modeling of radiation transport in X-ray targets provides valuable insight into the performance of a target, the emitted spectrum, its heat dissipation, and the influence of main design parameters.

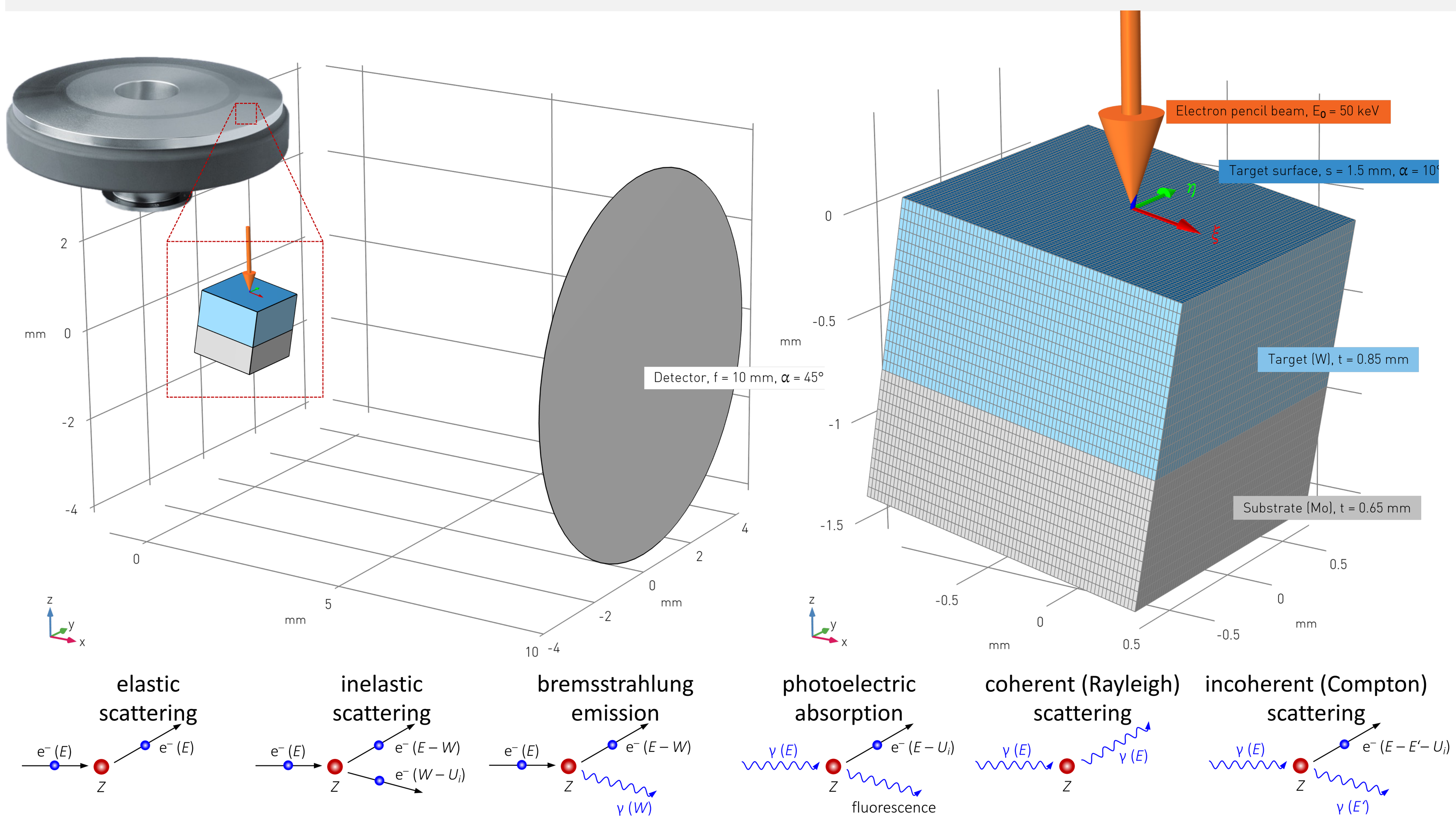

FIGURE 1. Schematic of X-ray target segment and detector (left), computational domain with accumulator grid (right), atomic interactions for electrons e^- and photons γ (bottom).

Methodology

Using the Monte Carlo method (Ref. 1) the cascades of electrons e^- and photons γ originating from primary electrons incident to the target surface are sampled. Particle histories are considered as random sequences of free flights with subsequent atomic interactions, some accompanied by secondary particle emission and electronic excitation.

The implementation based on the Particle Tracing Module accounts for all relevant atomic interactions (Figure 1) and makes use of efficient algorithms for sampling particle track and interaction characteristics (Ref. 1). Interaction data are compiled from EPICS-database (Ref. 2).

Dosimetry quantities are computed using accumulators, particle state variables allow statistical evaluations such as spectrum computation.

Results

Application is shown for of an inclined tungsten target bonded onto a molybdenum X-ray substrate (Figure 1) and exposed to an ideal monoenergetic 50 keV electron pencil beam (Ref. 3).

The X-ray photon emission is obtained in terms of fluence $\overline{\Phi}_\gamma$ and energy fluence $\overline{\Psi}_\gamma$ distributions per incident electron over the target surface (Figure 2). Only 3.75% of electron energy is transformed to emitted photon energy with the rest dissipated as heat in the solid target shown by the absorbed dose D distribution (top left).

Only 5% of the emission is registered by the detector (Figure 1), with the overall efficiency in the order of 0.1% agreeing well to practical experience and analytical estimates (Ref. 4).

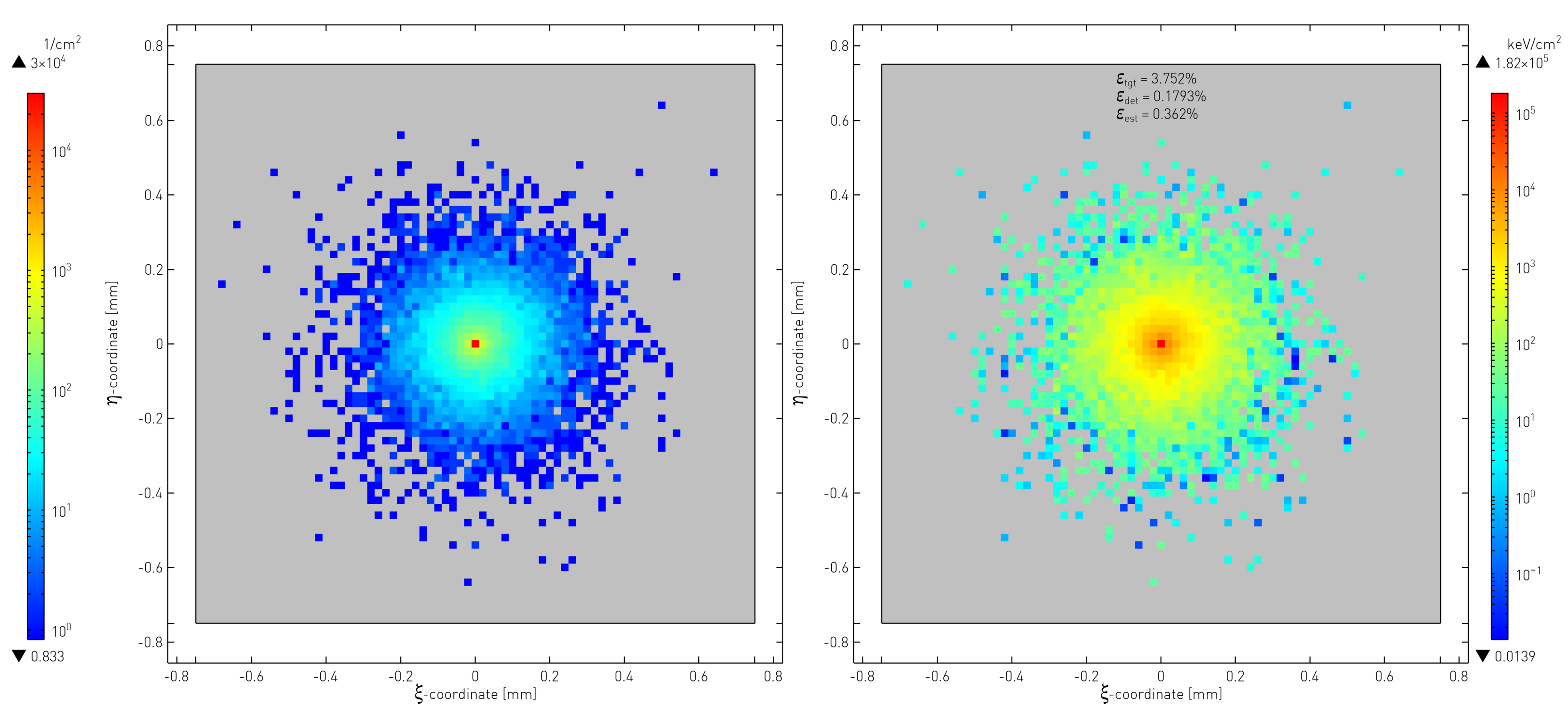

FIGURE 2. Photon fluence $\overline{\Phi}_\gamma$ (left) and photon energy fluence $\overline{\Psi}_\gamma$ (right) per incident electron for 50 keV pencil e-beam.

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