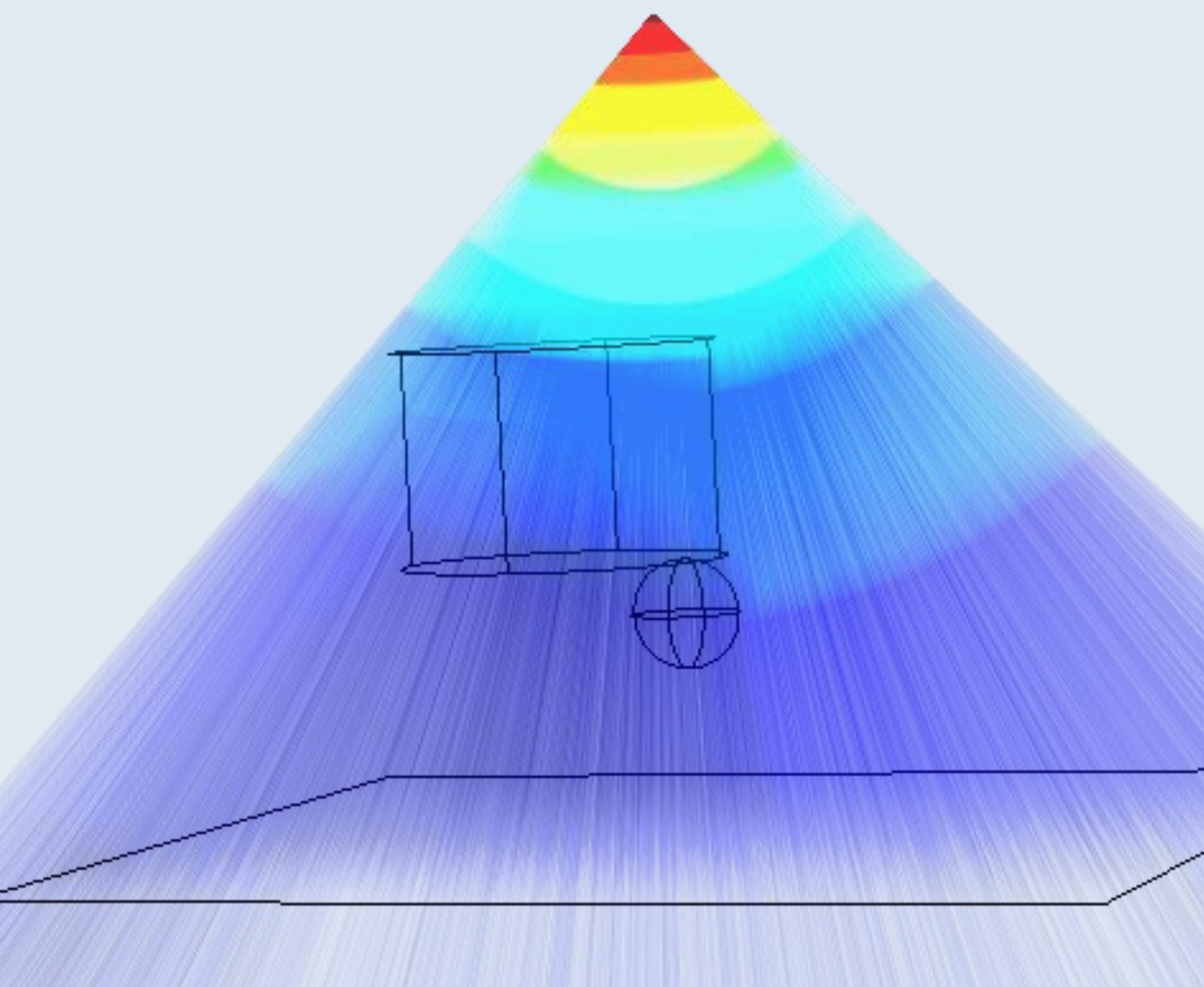




Synthetic X-Ray Radiograph Generation

This work introduces a new COMSOL Multiphysics® workflow that transforms the Ray Optics Module into a flexible platform for synthetic X-ray image generation using Beer–Lambert attenuation.

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Goals

COMSOL Multiphysics® does not provide a dedicated out-of-the-box workflow for synthetic X-ray image generation. This work explores how existing functionality in the Ray Optics Module can be adapted to create a virtual radiography workflow based on deterministic ray tracing and Beer–Lambert attenuation.

The main goals are to:

- Generate 2D X-ray projection images from 3D single- and multi-material objects.
- Compare two detector image-generation approaches: *Spot Diagram* and *Boundary Accumulator*.
- Validate the COMSOL-generated projections against Monte Carlo simulations and demonstrate multi-position acquisition for tomographic imaging.

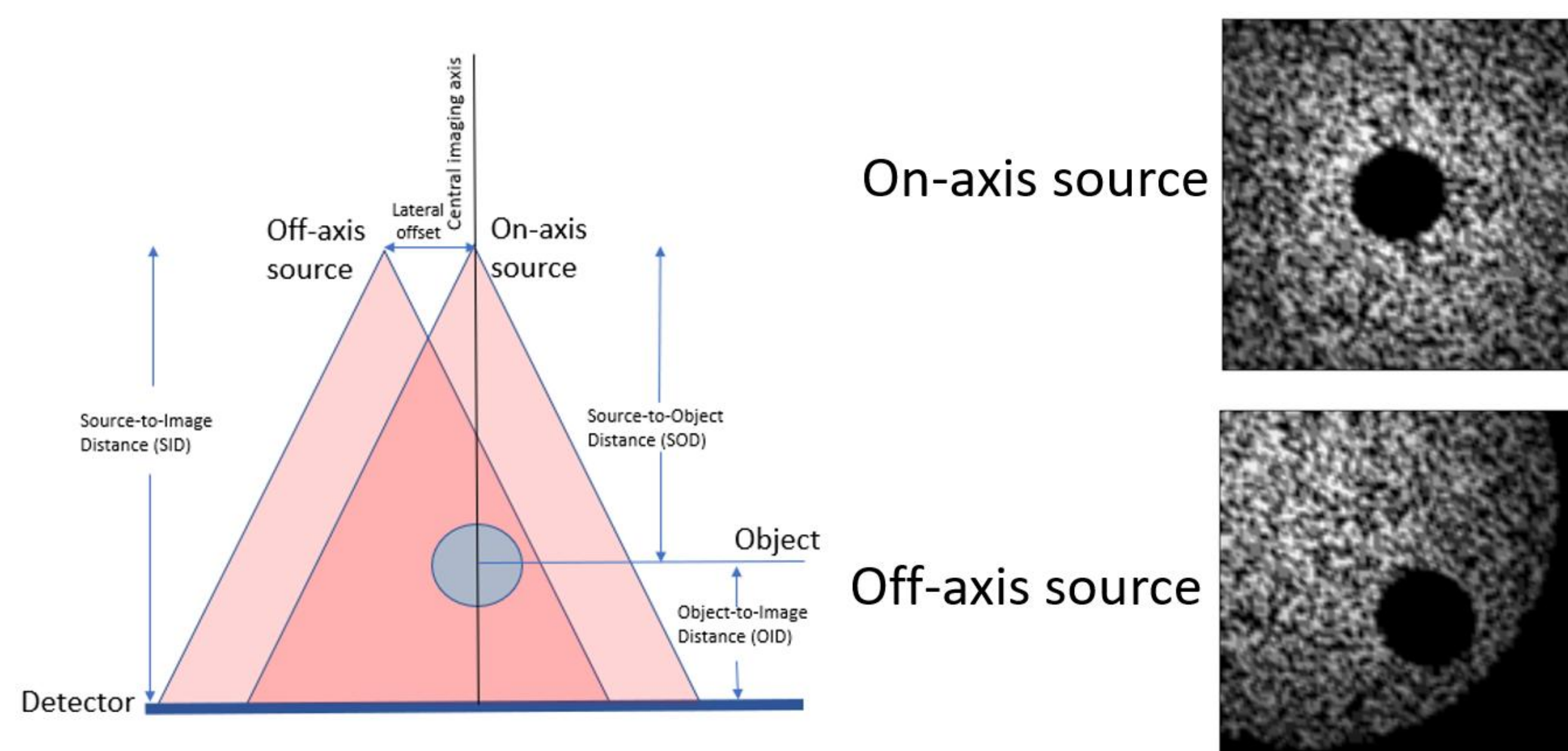


FIGURE 1. On-axis and off-axis X-ray imaging geometries showing source position, object, and source-to-object/source-to-image distances. Schematic of the simulated X-ray imaging geometry showing the source, object, and detector.

Methodology

1. **Ray generation:** Geometrical Optics rays are released from an X-ray source toward detector pixels.
2. **X-ray attenuation:** Material-dependent attenuation is calculated using the Beer–Lambert law.
3. **Image formation:** Transmitted ray intensity is mapped to detector coordinates using either the Spot Diagram or Boundary Accumulator approach.
4. **Multi-view acquisition:** Source position can be varied to generate a sequence of projections for tomographic reconstruction.

Results

- COMSOL-generated projections reproduced the expected material- and path-length-dependent attenuation.
- Results showed agreement with the Monte Carlo benchmark for the investigated case.
- Both Spot Diagram and Accumulator approaches can be used to construct 2D radiographs, with different detector representation and postprocessing requirements.
- Off-axis and multi-position source configurations can be simulated within the same framework.

Existing Ray Optics functionality can be adapted into a flexible synthetic radiography workflow for single- and multi-material geometries, off-axis imaging, and multi-position acquisition.

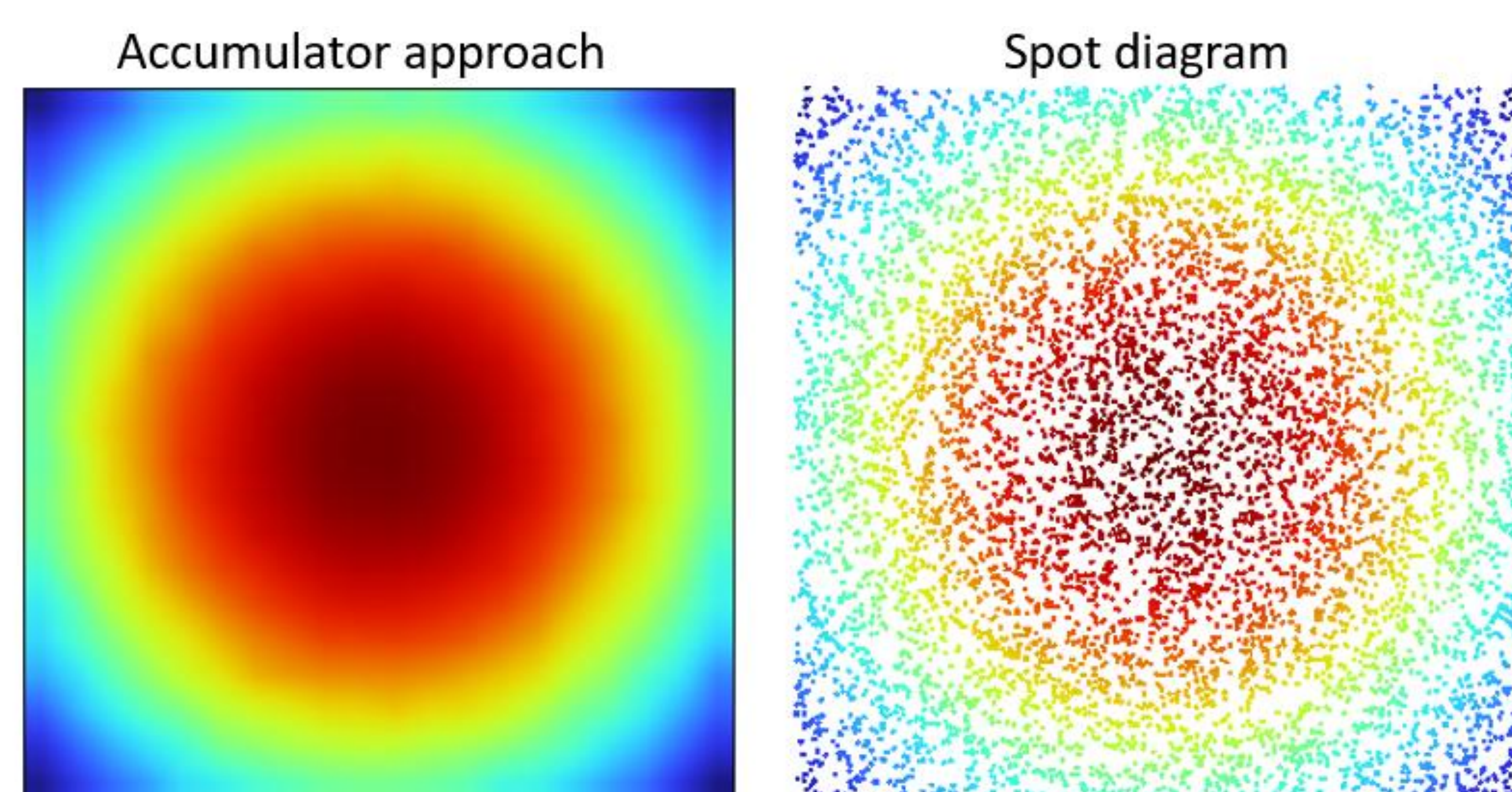


FIGURE 2. Generated X-ray image visualized within COMSOL interface using both methods: Accumulator and Spot diagram.

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