Spectral and Imaging Intensities and Fluxes Computed in SPECT3D

SPECT3D supports the following viewing geometries:

- Orthographic projection
- Point projection
- Spherical crystal geometry with a backlighter.

Point Projection viewing is typically used in cases where small backlighter sources are utilized. *Spherical Crystal* geometry is a special case for simulating backlit images using a monochromatic backlighter.

Figures 1 and 2 show schematic illustrations of the *Orthographic Projection* and *Point Projection* viewing models. In each case, the coordinate system of the target-plasma-backlighter system is defined to be that of the plasma coordinate system.

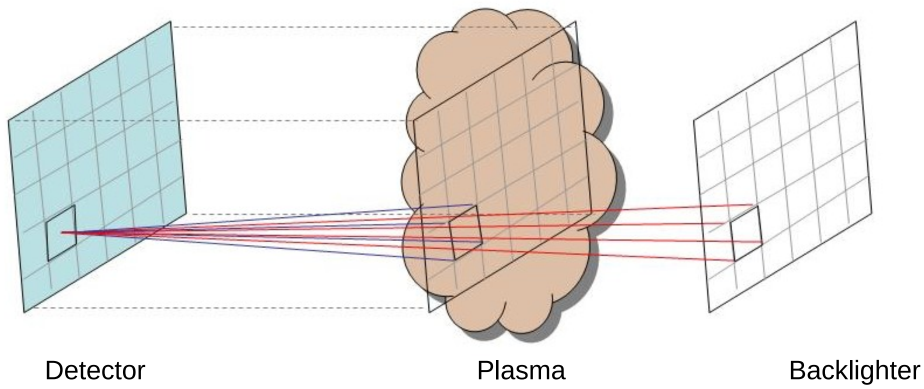

Figure 1. Schematic illustration of Orthographic Projection viewing model for a rectangular virtual detector in *SPECT3D*. The blue lines indicate solid angle to the plasma as viewed by a detector pixel, while the red lines indicate the solid angle to the backlighter.

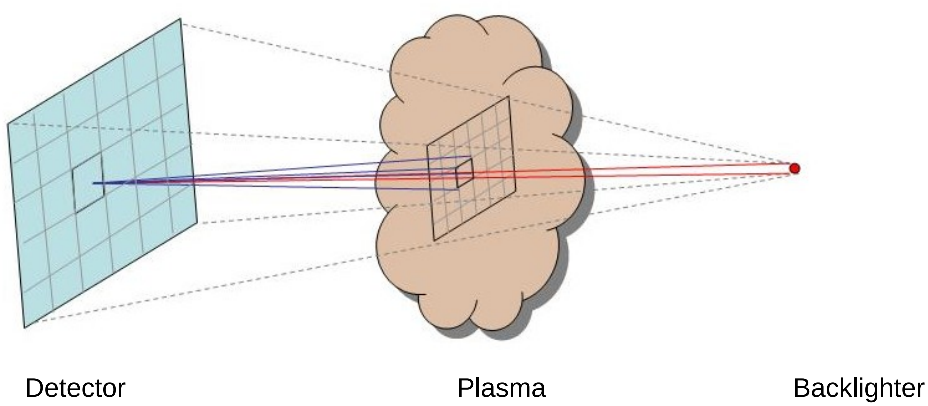

Figure 2. Schematic illustration of Point Projection viewing model for a rectangular virtual detector in *SPECT3D*. The blue lines indicate solid angle to the plasma as viewed by a detector pixel, while the red lines indicate the solid angle to the backlighter.

The detector position and size are specified by the user in the *Detector* setup dialog. The detector is divided into a grid of pixels (in the horizontal and vertical directions for a rectangular detector, and in the radial and azimuthal directions for a disk detector).

For *Orthographic Projection*, the rays shooting through the plasma from each detector pixel are parallel (see Fig. 1). When specifying *Orthographic Projection*, the center of the detector points at the user-specified *Center of Projection*. Backlighter effects can also be included when using *Orthographic Projection*. In this case, the position of the backlighter is located at the position defined by the *Center of Projection*, and the backlighter has an extended size that is equal to the size of the detector.

When *Point Projection* viewing is specified, the rays from each detector pixel are directed at the *Backlighter Position* (see Fig. 2). The *Backlighter Position* is specified on the *Detector* setup dialog, as it is used in defining the lines of sight from the detector through the plasma to the backlighter.

Figures 3 and 4 show the orientation of the detector, spherical crystal, target plasma, and backlighter for the *Spherical Crystal* geometry option. Figure 4 shows how lines of sight that originate from different parts of the detector reflect off the spherical crystal and move through the plasma to the backlighter.

Backlighter Spatial Intensity Profiles

Two types of backlighter *intensity profiles* are supported in *SPECT3D*: uniform and distributed. For a uniform backlighter, the intensity originating from the backlighter is assumed to be spatially uniform, and the specific intensity is computed along a single line of sight from the backlighter to each pixel in the detector plane. For a uniform backlighter, the size of the backlighter is used in computing the total flux seen at the detector.

For a backlighter with a distributed spatial profile, the intensity emitted from the backlighter is given by:

$$I(r) = I_0 \exp[-(r / r_0)^n] \qquad (1)$$

where I_0 is the intensity at the center of the backlighter spot, r is the radial distance from the center of the spot, and r_0 and n are user-specified constants. For backlighters with distributed spatial profiles, the backlighter is broken up into a grid of points, each of which casts a line of sight to each pixel in the detector plane.

Radiative Transfer

The specific intensity, I_ν, at a detector pixel is computed along each line of sight by solving the radiative transfer equation:

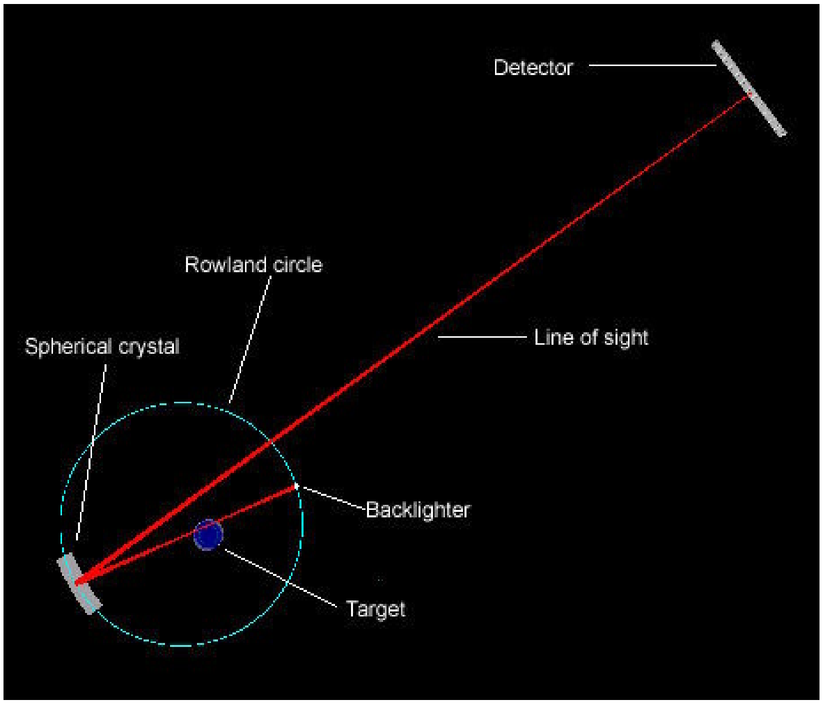

Figure 3. Schematic illustration of Spherical Crystal viewing model. The backlighter resides on the Roland circle. Photons from the backlighter propagate through the plasma, reflect off the spherical crystal, and are recorded at the detector.

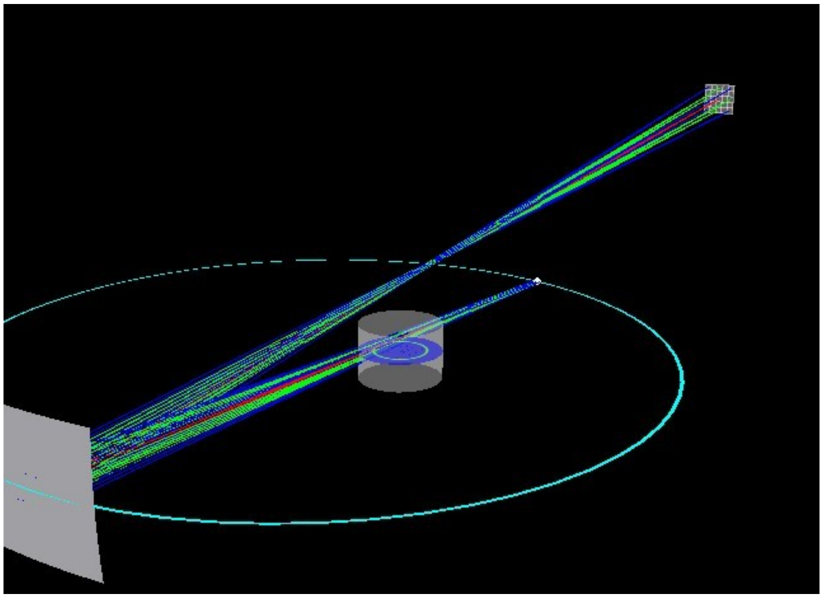

Figure 4. Schematic illustration of Spherical Crystal viewing model showing lines of sight originating from different points on the detector plane: center (red), sides (green), and corners (blue).

$$I_\nu^{Det} = I_\nu^{BL} e^{-\tau_{Max}} + \int_0^{\tau_{Max}} S_\nu \; e^{-\tau_\nu} \; d\tau_\nu \tag{2}$$

where

$$S_\nu = \eta_\nu / (\kappa_\nu + \sigma_\nu) \quad ,$$

$$\tau_\nu(z) = \int_0^z \kappa_\nu \; dz \quad ,$$

η_ν is the plasma emissivity at frequency ν, κ_ν is the absorption coefficient, σ_ν is the scattering coefficient, $\tau_\nu(z)$ is the optical depth as measured to a position *z* along the line of sight relative to the detector, τ_{Max} is the total optical depth along the line of sight, and I_ν^{BL} is the specific intensity at the back boundary of the plasma (defined by the backlighter intensity).

Radiation Flux at the Detector

The total flux *at the detector* at frequency ν, F_ν, is given by summing over lines of sight, ℓ:

$$F_\nu = \sum_{\ell}^{N_{LOS}} F_\nu^{\ell} \tag{3}$$

where

$$F_\nu^{\ell} = I_{\nu,\ell}^{P} \; \Delta\Omega_P^{\ell} \; + \; I_{\nu,\ell}^{BL} \; e^{-\tau_{\max}} \; \Delta\Omega_{BL} \quad ,$$

$I_\nu^P = I_{\nu,\ell}^{Det} - I_{\nu,\ell}^{BL} \; e^{-\tau_{\max}}$ is the contribution to the specific intensity at the detector that is due to the self-emission from the plasma, $\Delta\Omega_P^{\ell}$ is the solid angle of the plasma seen by the detector for line of sight ℓ, and $\Delta\Omega_{BL}$ is the solid angle of the backlighter seen by the detector.

In *SPECT3D Visualizer*, time-resolved *images* show the frequency-integrated specific intensity for each detector pixel:

$$I_\ell^{Det} = \int_{\nu_{\min}}^{\nu_{\max}} I_{\nu,\ell}^{Det} \; d\nu \quad , \tag{4}$$

where $\nu_{\min}$ and $\nu_{\max}$ are the minimum and maximum photon energies, respectively. In the case of filtered images, the intensities shown are:

$$I_{\ell}^{Det} = \int_{\nu_{\min}}^{\nu_{\max}} I_{\nu,\ell}^{Det}\ R_{\nu}\ d\nu \quad , \tag{5}$$

where R_{ν} is the frequency-dependent filter response function.

Time-resolved s*pectra* show the frequency-dependent flux at the detector. The 2-D space-integrated spectra (*i.e.*, integrated over the entire detector grid) are computed using Eq. (3). Horizontally and vertically resolved spectra are frequency-dependent spectra that are integrated in one dimension of the detector plane, but spatially resolved in the other dimension. In this case, the frequency-dependent flux at the detector *per resolution element* is displayed.