Fast Simulation of Local Radiation Fields for Synthetic Diagnostics

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We describe a technique based on the concept of Green's functions, which enables fast simulations of the local radiation fields and diagnostic signals for arbitrarily distributed volumetric sources. The technique is applicable to simulations of diagnostic signals for a range of neutron and optical diagnostics in tokamak plasmas. The development and validation of control algorithms for plasma scenarios in tokamaks require fast techniques for the simulation of the signals from plasma diagnostics. The signals should be realistic, i.e. correctly describe the source dynamics, geometry of detectors, and take into account reflection, scattering and dissipation of radiation in the real design geometry. Typically, accurate simulation of the signals requires the use of time consuming Monte-Carlo or ray-tracing codes using detailed 3D models of the reflecting, scattering, and absorbing elements affecting the diagnostic signals from the sources of radiation distributed in the plasma volume. Thus, computation of a realistic signal from evolving distributed volumetric sources of radiation becomes too time-consuming and expensive an exercise. For cases with additive impact of the sources on the diagnostic signal it is possible to use an approach based upon Green's functions, considering the function which transfers the source of radiation to the registered signal as a generalized operator. The matrix G_{ij} of the signals measured by a diagnostic from a set of unit ring sources on a chosen grid (R_i,Z_j) is calculated by comprehensive time consuming codes just once. This is then used for interpolation of the Green's function, $g(R,Z)$, to simulate a signal from an arbitrarily distributed evolving volumetric source, $S(R,Z;t)$: $F(t) = \int S(R,Z;t)g(R,Z)dV$. This analytic approximation enables simulations of the signals from sources computed on the grid of different complexity adapted to a specific source to keep the required accuracy and resolution. As an example, we discuss the application of proposed technique to simulations of the signals from the neutron diagnostics in ITER. Applications of this technique have enabled a reduction in the computational time needed for a signal from dozens of hours of parallel computations by the MCNP code to less than a second of CPU time. The Green's function matrix G_{ij} and base grid (R_i,Z_j) approach are recommended for the creation of synthetic diagnostics for ITER in the frame of IMAS.