Beam-Based Diffraction Tomography Projection-Slice Theorem

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Projection-slice relations are among the basic theorems in linearized diffraction tomography of scattering objects. The general formulation of the Diffraction Tomographic Projection-Slice theorems (DTPST) is based on a reciprocal domain — spectral (Fourier) domain — relation between a transformed version of some measured quantity ("projection") and a transformed version of the scattering object characteristic property ("contrast"). Within the Born or Rytov type linearization the measured quantity is, respectively, the complex amplitude or phase on, for example, planar screen. The tomographic experiment can be carried out with different type of exciting wave-fields, thus yielding, correspondingly, similar DTPST relations, all sharing the same general format but with different details that are imposed by the wave-field geometric manifold. Fourier based DTPST for plane-wave and spherical (point source) exciting wave-fields were discussed theoretically and experimentally by many authors in the past. The presentation concerns a DTPST with focused beam wave-field excitation and in particular a Gaussian beam type excitation. Focused beams belong to a multi-parameters family of wave-fields as opposed to the single parameter plane- or spherical- waves. In particular, Gaussian beam depends on two parameters: the location of the beam waist in space and the collimation (Rayleigh) distance. Thus, a control over the wave-front radii of curvature (whether converging or diverging toward the scattering object) and the spatial/spectral width of the exciting field are provided. Consequently, as will be shown, beam-based projection-slice formulation offers some advantages over the plane- and spherical wave-field excitations, such as spatial and spectral locality of the contrast profile that gives rise to a windowed version DTPST (W-DTPST) and extended spectral coverage with multi-experiments. Furthermore, both plan-wave and spherical-wave DTPST can be considered as limiting cases of the beam-based W-DTPST. In the presentation, a detailed derivation of the W-DTPST within paraxial scattering approximation, range of model's validity, parameter setting, spectral coverage and performance bounds will be discussed and demonstrated with some possible extensions to configurations that exploits some of the beam tracing advantages.