NONLINEAR CRYSTAL OPTICS

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Course description

This lecture focuses on fundamental crystal parametric optics that is one of the most fascinating field of nonlinear optics involving corpuscular and wave aspects of light in strong interaction with the electrons of matter, and leading to optical frequency synthesis and mixing at the origin of numerous applications.

1) Constitutive relations and Maxwell equations. **2)** Classification of the nonlinear interactions through the corpuscular approach: fusion and splitting involving three or four photons, spontaneous and stimulated processes. **3)** Calculation of the electric susceptibility by Lorentz model: perturbation approach leading to the definition of the different orders of the electric susceptibility, wavelength dispersion, intrinsic symmetries (Kleinman and ABDP), implications of spatial symmetry on the susceptibility tensors (Neumann principle). **4)** Tensor algebra and calculation of the first, second and third order polarizations. **5)** Modelling of the macroscopic nonlinearities of matter from the microscopic scale using the bond charge model and *ab initio* calculation, Miller index. **6)** Basics in linear crystal optics: propagation equation, index surface, birefringence, double refraction, eigenmodes. **7)** Amplitude equations in the nonlinear regime, Manley-Rowe relations. **8)** Calculation of the effective coefficient based on the field tensor formalism. **9)** Types and topology of collinear and non-collinear Birefringence Phase-matching and Quasi-Phase-Matching in bulk media and whispering-gallery-mode resonators. **10)** Conversion efficiency calculation of second harmonic generation (SHG), direct and cascaded third harmonic generation (THG), and optical parametric interactions: fluorescence, amplification (OPA), chirped pulse amplification (OPCPA), generation (OPG), oscillation (OPO). **11)** Angular, spectral and thermal acceptances. **12)** Spatial and temporal walk-off effects. **13)** Techniques of characterization of nonlinear crystals for the determination of phase-matching and quasi-phase-matching loci, magnitude and relative signs of the nonlinear coefficients, acceptances. **14)** The main materials for parametric generation, from ultraviolet to THz.