Optical crystals in laser physics: from physical foundations to applications

Aladin Mani
Atomic Energy Commission, Syria

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Abstract

This lecture explores the fascinating field of optical crystal science and its key applications in laser physics. It covers laser crystals such as neodymium-doped yttrium aluminium garnet ($Nd:Y_3Al_5O_{12}$), commonly known as Nd:YAG, as well as Nd:YLF, $Nd:YVO_4$, and titanium-doped sapphire ($Ti:Al_2O_3$), shortly Ti:sapphire. The discussion extends to electro-optic crystals such as monopotassium phosphate (KH_2PO_4), known as KD*P, potassium dideuterium phosphate (KD_2PO_4), known as KDP, and lithium niobate ($LiNbO_3$). It also covers nonlinear optical crystals such as beta barium borate (BBO), lithium triborate (LBO), potassium titanyl phosphate (KTP), lithium niobate (LiNbO3), and infrared crystals such as $AgGaS_2$, GaSe, and $ZnGeP_2$, among others. These materials are widely used in modern laser systems and photonic devices for frequency conversion, harmonics generation, parametric amplification, and other nonlinear processes, enabling laser beam generation, modulation, mode locking for ultrashort pulses and wavelength conversion across a broad spectral range—from the mid-infrared to the ultraviolet. Consequently, these crystals are fundamental building blocks for extending the capabilities of advanced laser systems applied in laser spectroscopy, laser ablation, laser surgery, laser light detection and ranging (LIDAR), and photonic integrated circuits (PICs), among many others. Such laser systems are widely used in academic research, industry, and medicine. The lecture will discuss the fundamentals of optical crystals and the criteria for selecting materials for specific applications, as well as highlight the author's own research contributions in this field.

About the lecturer

Dr Aladin Mani got his BSc in Solid State Physics from Damascus University, Syria, MSc in Optoelectronics from Liège University, Belgium and PhD from University of Namur, Belgium. He is an experienced academic researcher specialised in multidisciplinary research and development projects related to Laser Physics, Laser Spectroscopy and Microscopy, Photonics, Optoelectronics, Nonlinear Optics, and Multiphysics 3D Modelling. Currently, his research area includes the fields of Industrial Tunable Lasers from IR to UV Picosecond and Femtosecond Laser Systems, Optical Imaging Systems, and Ultrasonic Imaging Systems. Dr Mani is an author and co-author of more than 48 publications. He holds permanent position as Senior Researcher in Laser Physics Department of Atomic

Energy Commission, Syria. He served also as Principal Investigator and Senior Researcher in a number of scientific institutions worldwide such as University of Namur, Belgium, University of Limerick, Ireland as well as R&D Manager in LaserSpec, Belgium. He is an active member of OPTICA (formerly OSA). Dr Mani has over twenty years of experience in implementing national and international scientific projects within programmes such as Science Foundation Ireland, European Frame Programmes FP6, FP7 and H2020, etc.