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Recent advances in crystal optics/Avancées récentes en optique cristalline

Foreword

The great fascination of man for the beauty of gems could be considered as the seed of the history of crystal optics. The esthetical attraction for crystals is due to their geometrical shapes, their high brilliance and their huge palette of colours. In fact, we have here three characteristics linked respectively with three remarkable properties of crystals: symmetry, high electronic density, and the ability to stabilize numerous ionic valences; these are at the root of many aspects of modern optics.

Crystal optics really begins at the end of the 17th century with the discovery and study of birefringence and double refraction. The main subject of interest of these properties was in the study of crystallography during the 19th century, until the advent of X-ray diffraction. However, birefringence is the basis of polarizing microscopy that has persisted as a unique technique in mineralogy and petrology for the identification of mineral specimens. The 19th century was also very fruitful for crystal optics, with the successive discoveries of the phenomena of optical gyration, internal and external conical refractions, electro-optics and magneto-optics. Crystals definitely united their destiny with light in the middle of the 20th century with the invention of the first laser that was based on chromium ions doping a ruby crystal: a crystal was able to generate light with spectral, time and space confinement of the energy. Very soon after this major discovery, and thanks to the high power density of a laser beam, the first nonlinear optical parametric effect was observed, i.e. a second harmonic generation using a quartz crystal illuminated with the ruby laser. The birth of the laser has largely opened the field of optics, with respect to both fundamental and applicative aspects, and crystals have played, and continue to play, a major role in this fascinating story. Crystals, either organic or mineral, dielectric or semi-conductor, are privileged media for the generation of laser beams, as well as for their transformation via electro-optics, nonlinear optics or magneto-optics. An innovating technology has thus been developed over the past twenty years on the basis of crystal optics, leading to numerous applications in telecommunications, data storage, medicine, imaging, micromachining, spectroscopy and so on. It is evident that the progresses in optics strongly depend on materials science, including the conception of new compounds, the mastery of the techniques of elaboration, from thin layers to bulk crystals, and the design of specific methods of modelling and characterization. The recent advances in crystal optics address all these items, generally in a synergic approach.

This special issue aims at giving some major aspects of modern crystal optics, some of them recently reaching their level of maturity while others constitute exciting challenges for the near future. Three articles are devoted to luminescent ion doped dielectric materials. "*Optical waveguides in laser crystals*" and "*Ceramic YAG lasers*" describe two important changes that definitely place this class of materials at the heart of integrated compact systems, the goal being to combine miniaturization with high optical power, brightness and tunability. The field of ultra-fast lasers continues to progress strongly in terms of pulse duration and compactness thanks to the development of new materials that can be directly pumped by high power semiconductor lasers, as shown in "*New laser crystals for the generation of ultra-short pulses*". Nonlinear optics continues to play a major and innovating role in laser optics as depicted in a series of six articles. "*Nonlinear polarimetry of molecular crystals down to the nanoscale*" shows how the combination of second harmonic generation and two photon induced fluorescence constitutes a unique tool for fundamental studies and characterization of nanocrystals, which is a crucial point for the development of nanosources and nanosensors. In "*Quasi-phase-matching*" are described the impressive performance of microstructured ferroelectrics and semiconductors in which can be tailored the spatial and spectral properties of laser beams through parametric nonlinear interactions in regimes inaccessible to conventional media. Nonlinear optics is a physics that reveals in a

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fascinating way the quantum properties of light; "*Spatial quantum optical properties of cw optical parametric amplification*" and "*Triple photons: a challenge in nonlinear and quantum optics*" describe two new fields recently opened and dealing, respectively, with quantum imaging using twin photons and with triple photons that constitute a new state of light. "*Quadratic spatial solitons*" explains how second order nonlinear processes involving two or three different frequency components can lead to a wave propagation without change in shape and amplitude, a key feature for optical communication. Nonlinear optics are efficient for the compensation of wave-front distortion and thermal lensing by using photorefractive crystals, as explained in "*Review of photorefractive materials: an application to laser beam cleanup*". It is absolutely necessary to develop specific optical measurements of semiconductors in order to push further the frontiers of electronics and optoelectronics; "*Semiconductor heterostructures for spintronics and quantum information*" shows how optics can be astutely used for the study and manipulation of quantum wells and quantum dots. This special issue ends with "*Photonic crystals: basic concepts and devices*"; these fascinating objects are based on an artificial spatial structuring of material at the wavelength scale leading to 1D, 2D and 3D modulations of the refractive index and opening a huge range of innovating concepts for advanced applications of photonics. I hope that these eleven articles will allow the reader to appreciate the variety and topicality of crystal optics.

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