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Physics of Fast Processes in Scintillators

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Preface

During the last two decades, an impressive progress has been made in fundamental understanding, engineering, and applications of inorganic scintillators. All steps of the transformation of energy in scintillators, production of secondary electronic excitations, thermalization, migration and recombination, and light emission, are considered, and models proposed show good potential for the scintillation property description and prediction as well. As a result, much understanding of complicated features of the phenomenon, like nonproportionality problem, has been demonstrated. One can mention results on interdependence of nonproportionality and deterioration of scintillator energy resolution. Recently, some additional factors which deteriorate energy resolution, like excitation cluster formation, have been augmented.

Nevertheless, new demanding applications of the materials require combining both high energy and time resolutions. It inspired new development for the basic principles of primary processes in energy relaxation, which plays a key role in formation of scintillating centers. The processes are characterized by quite different spatial and time scales. These scales differ for various classes of scintillators, depending on the electron structure of conduction and valence bands, energy position of core levels, phonon spectrum, presence of activators and dopants. Therefore, the microscopic structure of electronically and vibrationally excited regions is material-dependent. In general, this structure is characterized by high nonhomogeneity and controls relaxation and energy transfer rates. The goal is to make them faster, occurring in a ps domain or even faster, to ensure that the timing characteristics of scintillation detectors do not encounter new challenges in view of the demand for substantially shorter response time in the experiments at high-luminosity colliders and medical applications like time-of-flight positron emission tomography. The feasibility of the substantial improvement of timing in radiation detection systems based on scintillators is supported by the recently substantial improvements of time characteristics of the electronic readout, especially, by the advances in development of fast silicon photomultipliers.

Nowadays, further theoretical and simulation efforts towards a picosecond timing target are accompanied by the study of fast optical phenomena to be exploited for timing of material-radiation interaction.

The book considers the fast processes in the scintillation materials, giving much deeper understanding of the fundamental processes in scintillation. The theoretical and ps-spectroscopy research results, performed by the authors during the last decade, showed the way to engineering and to controlling energy transfer processes in the scintillation materials. It opens door for using the scintillators for precise time tagging of events at the level of ten picoseconds or even better. This initiates new era in high-energy physics instrumentation with ultimate timing performance, medical imaging, and industrial applications.

This book reviews modern trends in the description of the scintillation build-up process, particularly in inorganic materials, transient phenomena, and engineering of the scintillation properties. The readers will find in the book, besides reliable scientific background, educational information and new ideas to implement in their own research and engineering as well. Particularly, it will be of interest for students of different levels, university teachers, and researchers, allowing them to catch an overall picture of a progressively developing study, having immediate implementation in technology.

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Mikhail Korzhik (Korjik) graduated in Physics from the Belarus State University in 1981 and received his PhD degree in 1991 and his Doctoral Diploma in Nuclear Physics and Optics in 2005. Since the beginning of the 1990s, he was deeply involved in the research and development of inorganic scintillation materials. He was instrumental in the development of the technology of a few oxide scintillation materials, pioneering the Pr^{3+}-doped scintillation materials. His study promoted the understanding of scintillation mechanisms in many crystals. He took part in the discovery and development of mass production technology of lead tungstate $PbWO_4$ scintillation crystal for high-energy physics applications including exploitation of this crystal in two ambitious LHC experiments, CMS and ALICE, first of which made an important contribution to the discovery of the Higgs boson. He is a member of the Scientific Advisory Committee of SCINT and a chairman of ISMART biannual international conferences dedicated to the development of scintillation materials.

Gintautas Tamulaitis graduated in Physics in 1979 and received his PhD degree in 1985 and habilitated doctor degree in 2001 from Vilnius University, where he currently works as a professor. He received two Lithuanian National Science Awards (in 2002 and 2008) and did research as a visiting researcher at the University of California, Berkeley, the University of South Carolina, and the Rensselaer Polytechnic Institute. His main research background is in the experimental study of nonequilibrium quasiparticles in semiconductors and their low-dimensional structures by using time-resolved and spatially resolved photoluminescence spectroscopy and techniques based on nonlinear optics. Currently, his research is focused on the study of fast nonlinear optical processes to be exploited in future radiation detectors with timing of the order of 10 ps and search for novel single crystal materials and glass ceramics prospective as fast scintillators.

Andrey N. Vasil'ev graduated from the Faculty of Physics at Lomonosov Moscow State University in 1975 and received his PhD degree in Theoretical and

Mathematical Physics in 1978 and his Doctoral Diploma in Optics in 1995. He is a department head at Skobeltsyn Institute of Nuclear Physics of Lomonosov Moscow State University. His main activities were focused on the investigation of luminescence of inorganic insulators excited by VUV and X-ray synchrotron radiation and by ionizing particles. His in-depth study of all stages of energy relaxation in scintillators contributed to contemporary understanding of nonproportionality, formation of light yield, response kinetics, and energy resolution of scintillators. He is a member of the Scientific Advisory Committee of the International Conference SCINT.