

# Preface

The idea of this volume was originally to provide a state-of-the-art review and perspective of laser technologies addressed at implementing compact particle accelerators for biological researches and clinical uses. As long as the editorial work was progressing, it was more and more clear that the expectation level for this novel technology is quite high in a broad community of scientists, including laser, plasma and nuclear physicists, medical physicists, radiation biologists, radiologists. Contributions from each one of these classes of expertise became highly desirable and luckily they were offered by some of the leading experts and groups presently operating in these fields.

So, the original scheme expanded its branches like a fruitful tree. Physicists involved in the particle acceleration with laser techniques, provided not only the state of the art of laser-driven electron, proton and ion accelerators most suitable for biological studies and future clinical therapies, but also a deep insight of the most advanced experiments and novel ideas. It comes out that laser-produced particles beams have been already used in a variety of physical processes to generate secondary sources of high-energy photons, another kind of ionizing radiation. In turn, photons of tens of MeV have been used to produce, via photonuclear reactions, radionuclides of interest for the nuclear medicine. The reader will also discover how high-resolution ultrafast radiography can be easily performed with particles accelerated by laser.

On the other hand, radiotherapists describe some of the most advanced RF-based devices and protocols, extremely effective, they actually use in a hospital. The novel practice in radiotherapy of tumors is the benchmark (continuously moving forward) for the laser-driven technologies. While a number of biologists are systematically investigating the response of living matter to the particle bunches produced by lasers, some others are already speculating on how this new opportunity can extend and empower the most recent concepts of radiobiology.

A major point to be addressed by the research is the extremely shorter duration of bunches produced by laser with respect to bunches produced by conventional accelerators. A factor exceeding 1,000,000 is involved, from  $\mu\text{s}$  to sub-ps timescale.

The ultrashort duration of laser-produced particle bunches may involve unexpected consequences for cancer therapy. In fact, it is not known if delivering the same dose with particles of the same kinetic energy but at much higher instantaneous dose-rate may lead to a different tissutal effects with possible consequences on therapeutic strategies.

From the physical point of view, we can expect that the extreme particle density we can reach in a bunch with laser acceleration could produce some nonlinear or “collective” effects which cannot be described by the usual single-particle Monte Carlo simulation. In other words, it is possible that each ultradense bunch of electrons could produce not only the statistic sum of the effects of each low-LET particle but also some high-LET effect due to the total charge involved. If this would be true, the biological action could not only concern DNA but also some structural cellular feature, like membrane.

This major issue, in turn, calls for a dedicated research on radiobiological effects to be performed with the ultrashort particle bunches produced by laser technology. It is evident that such a research also has a high conceptual value since it enables, for the first time, the investigation of very early processes occurring in the time-scales of physical, chemical, biological responses of the living matter to ionizing radiation. The action of such kind of radiation can be followed for the first time on femtosecond time scale and nanometric spatial scale.

The novel acceleration technologies, based on the interaction of ultrashort intense laser pulses with matter, delivering sub-picosecond pulses of ionizing radiation, also demand a general renewing of dosimetry and safety protocols. Both absolute and relative dosimetry are reconsidered, in the framework of international protocols. While suitable existing devices are examined, including radiochromic foils, ionization chambers, and Faraday cups, novel concepts for ad hoc detectors are introduced and need to be carefully investigated. Dosimetric simulations with Monte Carlo methods, in particular with the GEANT4 toolkit, provide a precious support to this effort.

Also radiological safety has to be reconsidered while thinking to transfer technologies based on high-power lasers in a clinical context. It is not exactly the same issue as with conventional accelerators delivering a well defined type of particle with an almost monoenergetic spectrum. We are dealing now with a mix of radiological products delivered by laser–matter interaction, at a given but changeable intensity, with a variety of materials acting as accelerating media. Of course this kind of problems have already been faced in high-power laser facilities devoted to studies on laser–matter interactions and in particular to particle acceleration, but for a medical facility the safety of patients and personnel is paramount, then also doses from any secondary radiation and any kind of other hazards have to be carefully minimized.

This volume tries to introduce the reader to the complex conceptual system growing very quickly from the advent of laser-driven particle acceleration and leading to a concrete expectation of benefits for basic knowledge and health care. The multidisciplinary contribution of several experts and research groups has been organized in 12 chapters, which in turn have been grouped into three parts, each one

including four chapters organized by major issues rather than by disciplines. A general introduction precedes the 12 chapters, while the volume is opened with a dedication to Prof. Wolfgang Sandner, whose memory is strongly linked to all the scientific efforts and successes in this field.

The editorial effort, hard as usual, was largely compensated by the enthusiastic support and friendly attitude of all the authors as well as of a few colleagues from the ILIL group of National Institute of Optics in Pisa.

The editor cannot personally forget the continuous lovely encouragement of his wife Angelica.

Pisa, Italy

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