Preface to the Second Edition

Observation of a gravitational wave is the most spectacular recent application of a laser (published in Physical Review Letters, February 2016). Four Nobel Prizes in the last four years for achievements in physics and chemistry (see Sect. 1.9 of the book) demonstrate the significance of lasers for scientific research. There is a steady development of lasers and of their use in scientific research in physics, chemistry, engineering, biophysics, medicine, and technical applications. Important progress has been made in the last years in the development and application of infrared and far-infrared free-electron lasers, and of X-ray free-electron lasers. X-ray free-electron lasers are opening new possibilities in scientific research and in application.

The first edition of the textbook *Basics of Laser Physics* presented a *modulation model of a free-electron laser*, illustrating dynamical processes in a free-electron laser. The second edition gives a modified treatment of the model. The model provides analytical expressions for the gain and for the saturation field of radiation in a free-electron laser. The results drawn from the modulation model are consistent with the results of theory that is based on Maxwell's equations; main results of theory arise from numerical solutions of Maxwell's equations. In accord with the modulation model is a description of the active medium of a free-electron laser as a quantum system, already discussed in the first edition: an electron, which performs an oscillation in a spatially periodic magnetic field, may be describable as an electron occupying an energy level of an energy-ladder system; accordingly, electronic transitions between the energy levels are origin of spontaneous and stimulated emission of radiation.

In order to stress features that are common to a conventional laser and a free-electron laser or show differences, various points are clearly structured in the new edition, such as the role of dephasing between a radiation field and an oscillator or Lorentzian-like functions (denoted as "Lorentz functions") describing frequency dependences of gain near or outside resonances. The second edition contains additionally: classical oscillator model of a laser (van der Pol equation of a laser); onset of laser oscillation of a titanium–sapphire laser; discussion of differences between a conventional laser and a free-electron laser; and a modification of the description of the yet hypothetical Bloch laser.

Additional problems should provide a deepening of the understanding of lasers. Furthermore, errors are corrected. The principle of the overall representation remains unchanged: this book is designed in a way that a student can study many of the chapters without special knowledge of the preceding chapters. In most chapters, the content develops from a more general aspect to specific aspects. Let me mention a particular point-concerning notation. I am using, besides the letter N for the number of particles per unit volume, the letter Z for the number (=*Zahl*, German) of photons per unit volume, instead of common combinations of a Latin and a Greek letter, or of an upper- and a lower-case letter.

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