

Preface

People working in the world of organic photonics and organic electronics are used to hearing the following statement: a prerequisite to success in this field is to acquire interdisciplinary knowledge “at the crossroads” between at least two or three domains: chemistry, material science, electronics, and photonics. Working on organic lasers is no exception to this rule, and requires at the same time solid foundations in laser physics and photonics, mixed with a good knowledge of photophysics of organic π -conjugated systems. This is probably what makes this field so exciting and collaborations so fruitful. However, this also raises some difficulties in transmitting knowledge and know-how to students or newcomers in the field having totally different backgrounds.

The authors have experienced this challenge, as they started in the field a few years ago, coming with a previous knowledge in laser physics and photonics, but no experience with organics. They wrote this book with the following guideline in mind: gathering in the same place introductory material, designed to give to a reader with no particular background in organic photophysics the keys to understand the challenges in the field, together with a state of the art, at the time of writing, of the recent advances and trends in organic lasers.

Why Organic Solid-State Lasers?

The story of organic lasers is almost as long as the history of lasers themselves: while the very first laser came to birth in 1960 [1], the first organic laser followed soon after, in 1966 [2, 3]. Organic lasers were at that time known as liquid “dye” lasers, a term inherited from the textile industry, and based on solutions of π -conjugated highly luminescent molecules. This kind of sources marked a true revolution in laser science, as the first widely tunable laser sources [4], leading to impressive progresses in spectroscopy in the following years. Additionally, the unique broad spectrum of organic dyes, coupled to the possibility of continuous-wave operation demonstrated in 1970 [5] opened the door to the first ultrashort (femtosecond) laser [6, 7]. Although often considered now far from being “user-friendly”, liquid dye laser are still today popular in laboratories as sources of

tunable visible radiation. However, their cumbersome designs, their liquid state, and the inconvenience linked to toxic solvents and dyes prevent them from being used for “real life” applications. Very early (as soon as 1967) it was then proposed to incorporate dyes in solid-state polymeric matrices [4] which appeared to be a promising route to build broadly tunable sources that would have the benefit to be compact, convenient, and manufactured at low costs. However, organic solid-state lasers did not manage, from then and up to now, to enter the marketplace: the main reason is probably that there is a fundamental economic contradiction between the inherent bad photostability of organic molecules and the high cost of the pump source, in general a pulsed laser. Subsequent efforts then naturally went in the direction of improving the dye and host matrix photostability, and/or decreasing the required pump threshold intensity so that alternatives to pulsed lasers may be found.

The field of organic solid-state lasers experienced a second birth at the end of the 1990s, following the discovery of organic semiconductors (mainly driven by the potentially huge market foreseen for Organic Light-Emitting Diodes [8]), and progresses came both from material science and deposition process technology. Very low thresholds could be demonstrated in thin-film based organic semiconductor lasers; furthermore, the devices turned out to be easy-to-handle and compact, while keeping all the advantages of organic materials [9, 10]. The question was then whether an *organic laser diode* would be ever realized, that is a device pumped with an injected current rather than with an optical source, in the same way as inorganic semiconductor lasers work. This issue drove considerable efforts and is still now a major inspiration railroad for organic laser research, although no demonstration of such a device has been reported yet.

The first two chapters are written in a “back-to-basics” spirit, with in-depth (although non exhaustive) description of the physics useful for entering the pluridisciplinary field of organic lasers. The next chapters deal with very recent research, reviewing state of the art and last trends in the field (for the interested reader, complementary information can also be found in some recently published review papers [11–13]). The book is organized as follows:

Chapter 1 is dedicated to the reader not familiar with lasers physics. It proposes a quick and simple picture of the main laser principles, but is not intended to explain laser physics in depth, as this task is performed in an impressive number of excellent teaching books [14, 15].

In **Chap. 2**, we introduce the specificities linked to organic materials as lasing media. To this aim, we first remind some photophysics basics that are useful to understand the following, before detailing the various aspects important for organic lasers and specific to them, and which are therefore not usually treated in classical textbooks on lasers. A first question that we may try to answer in this chapter is the following: what are the key features that make organic solid-state lasers (OSSL) different from other types of lasers, like those based on inorganic semiconductors, rare-earth doped crystals, or gas mixtures, to name a few? This chapter has been written with the intention to present organic laser physics and relevant photophysics at a basic introductory level, hoping that it will be accessible

for a reader with a background in general physics and laser physics but with no specific knowledge in photophysics.

Chapter 3 is devoted to organic materials, both dyes and organic semiconductors, from the description of their chemical structure and emission properties (and the way to measure them, especially optical gain) until the description of the fabrication techniques mainly used to make devices out of them.

In **Chap. 4**, the focus is set on the lasing architectures. Organic materials can be shaped and processed in such various ways that almost every resonator configuration can be adapted to them. Recent results for each cavity type are reviewed, with special emphasis on periodically structured resonators and vertical external cavity surface-emitting lasers.

Chapter 5 is a review of the last advances in the field of organic solid-state lasers, including the quest for electrically driven organic lasers, indirect pumping solution featuring inorganic diodes, as well as promising results in the field of nanoplasmonics where organic materials have an interesting role to play.

Finally, **Chap. 6**, the last chapter deals with the rapidly growing applications of organic lasers. The natural playground associated to organic lasers is spectroscopy, where the modest output power is not problematic and broad wavelength agility is a strong advantage. The simplicity of the fabrication process now makes organic sources attractive for integration onto miniature spectroscopic systems. More recently, organic lasers have been also used for chemical sensing, for example to detect trinitrotoluene (TNT) using conjugated polymer films [16]. The easy integration of organic solid-state lasers makes them ideal sources for lab-on-a chip sensors for biophotonics, coupled to microfluidic devices [17]. Organic semiconductor lasers may also find their place in data communications, for short-haul data transfer or optical amplifiers for example.

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References

1. T.H. Maiman, *Nature*. **187**, 493 (1960)
2. P.P. Sorokin, R. Lankard, Stimulated emission observed from an organic dye, chloro-aluminium phthalocyanine. *IBM J. Res. Develop.* **10**, 162–163 (1966)

3. F.P. Schafer, W. Schmidt, J. Volze, Organic dye solution laser. *Appl. Phys. Lett.* **9**(8), 306–309 (1966)
4. B.H. Soffer, B.B. McFarland, Continuously tunable, narrow-band organic dye lasers. *Appl. Phys. Lett.* **10**(10), 266 (1967)
5. O.G. Peterson, S.A. Tuccio, B.B. Snively, {CW} operation of an organic dye solution laser. *Appl. Phys. Lett.* **17**(6), 245–7 (1970)
6. E.P. Ippen, C.V. Shank, A. Dienes, Passive mode locking of the cw dye laser. *Appl. Phys. Lett.* **21**(8), 348–350 (1972)
7. R.L. Fork, B.I. Greene, C.V. Shank, Generation of optical pulses shorter than 0.1 psec by colliding pulse mode locking. *Appl. Phys. Lett.* **38**(9), 671–672 (1981)
8. C.W. Tang, S.A. Vanslyke, Organic electroluminescent diodes. *Appl. Phys. Lett.* **51**(12), 913–915 (1987)
9. N. Tessler, G.J. Denton, R.H. Friend, Lasing from conjugated-polymer microcavities. *Nature*. **382**(6593), 695–697 (1996)
10. F. Hide et al., Semiconducting polymers: A new class of solid-state laser materials. *Science*. **273**(5283), 1833–1836 (1996)
11. I.D.W. Samuel, G.A. Turnbull, Organic semiconductor lasers. *Chem. Rev.* **107**(4), 1272–1295 (2007)
12. S. Chénais, S. Forget, Recent advances in solid-state organic lasers. *Polym. Int.* **61**(3), 390–406 (2012)
13. C. Givras, M. Pollnau, Organic solid-state integrated amplifiers and lasers. *Laser and Photonics Rev.* **6**(4), 419–462 (2012)
14. A.E. Siegman, *Lasers*. (1986)
15. O. Svelto, *Principles of Lasers*. (Macmillan Publishers Limited, New York, 1998)
16. J.S. Yang, T.M. Swager, Fluorescent porous polymer films as TNT chemosensors: Electronic and structural effects. *J. Am. Chem. Soc.* **120**(46), 11864–11873 (1998)
17. C. Vannahme et al., Plastic lab-on-a-chip for fluorescence excitation with integrated organic semiconductor lasers. *Opt. Express*. **19**(9), 8179 (2011)

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