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XXXVI Cycle

High power LASERs for medical applications

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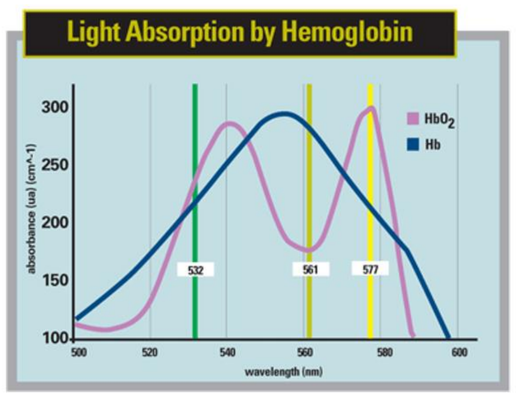
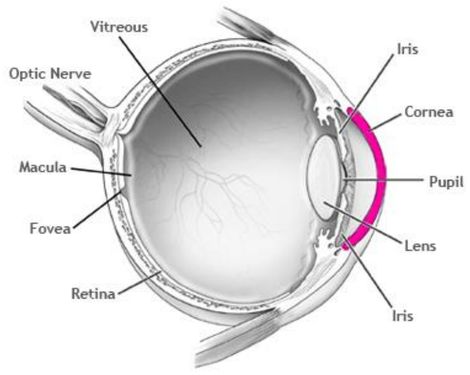
Research context and motivation

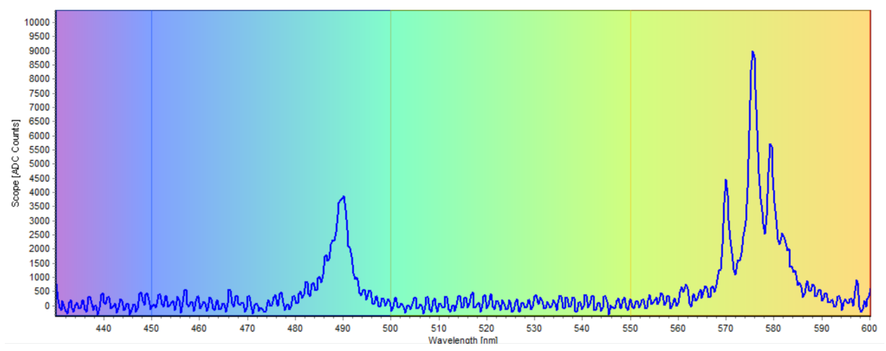
- The ageing of the population is causing a fast growth of ocular diseases leading to blindness such as **macular degeneration**, **glaucoma**, and **diabetic retinopathy**.
- These pathologies can be effectively treated with yellow laser light (**~577 nm, 1-5 W**) because this wavelength is highly absorbed by **O_2** and **Hb**, but not by **foveal pigments.** This allows a successful treatment of pathologies with less risks of affecting the fovea, which is the portion of the eye responsible for accurate vision.
- Yellow lasers currently available on the market are mainly based on frequency conversion (second harmonic generation) with consequent limitations in power stability, optical conversion efficiency and reliability.



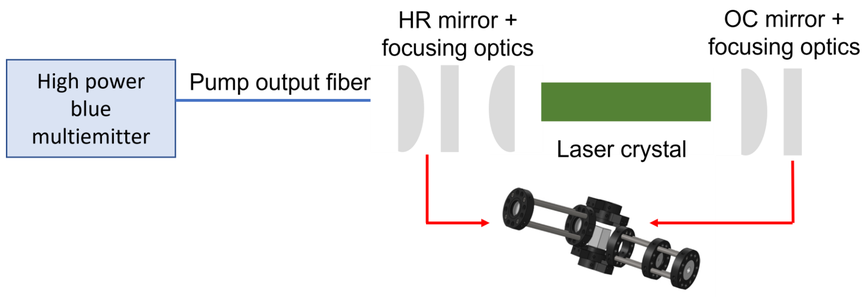


Addressed research questions/problems

- The aim of the research is the development of a yellow laser based on **direct emission** from a Dysprosium (Dy)-doped material pumped by blue/violet laser diodes (400-450 nm). We take advantage of new multi-emitter blue lasers that rely on the combination of chip-on-carrier diodes: this choice allows obtaining more compact sources and with a higher beam quality.



- Two possible laser implementation are studied and experimentally validated:
  - **DPSS (Diode-pumped Solid-state) laser** based on a Dy:YLF crystal. In this case the final device will be an extremely compact laser cavity, especially designed for medical treatments requiring pulsed regimes.
  - **Dy-doped fluoride or phosphate fiber laser**. This is the most promising solution for its flexibility and robustness, but the implementation requires solving many critical points, such as the silicate fiber pump to the soft glass active fiber splice and the lack of in-fiber components for the cavity mirrors.

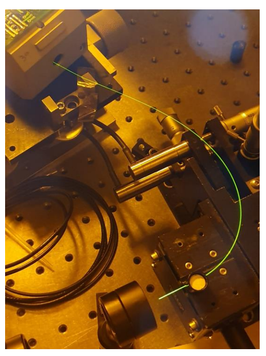


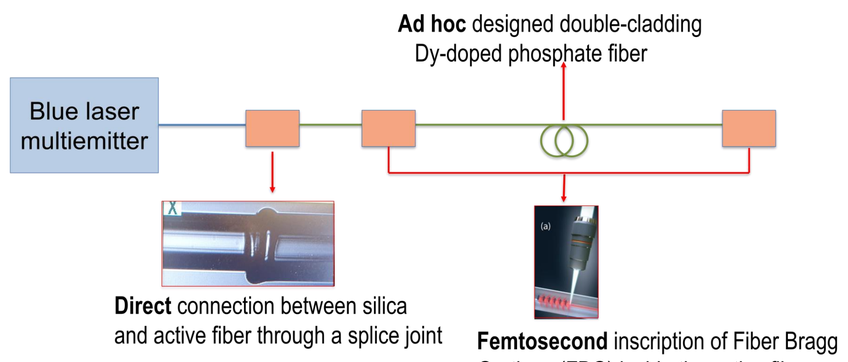
Submitted and published works

- A. Beccaria, A. Bellone, A. Mirigaldi, V. Serafini, M. Olivero, A. Vallan, G. Perrone "*Temperature monitoring of tumor hyperthermal treatments with optical fibers: comparison of distributed and quasi-distributed techniques*", vol. 60, 2020
- M. Olivero, A. Mirigaldi, V.Serafini, W. Blanc, M. Benabdesselam, F. Mady, C. Molardi, D. Tosi, A. Vallan, G. Perrone, "*Preliminary investigation of radiation dose sensors based on aluminum-doped silicate optical fibers*", IEEE International Symposium on Medical Measurements and Applications (MeMeA), Bari,. 2020
- V. Serafini, M. Riva, G. Pippione, A. Mirigaldi, C. Coriasso, S. Codato, P. Gotta, A. Maina, R. Paoletti, G. Perrone
- , "*Compact high-brightness and highly manufacturable blue laser modules*" ,Photonics West 2021, SPIE LASE, San Francisco, 2021

Novel contributions

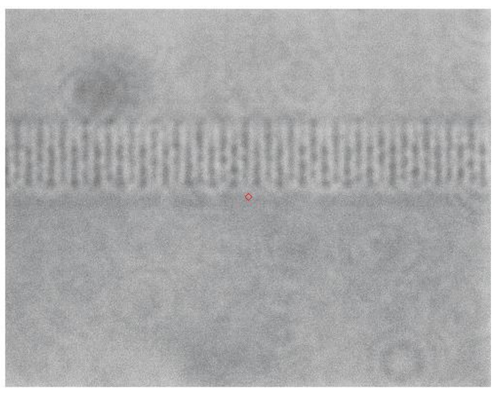
- The PhD research activity is partially within the PRIN2020 project **Yellow-FLiCkEr.**





Adopted methodologies

- **Ad-hoc Matlab simulation programs** developed for crystal and fiber laser cases. The programs can be used first to extract the active fiber characteristic parameters (e.g., cross sections, which are typically not disclosed by manufacturers) from a set of input power-output power curves; then to optimize the laser behavior.
- **High quality splicing procedures** for silica-ZBLAN and silica-phosphate fiber joints. The challenge comes from the large difference in the glass transition temperature between the silica fiber (1215 ◦C) and a soft glass fiber (180–300 ◦C). For this an asymmetric splice using a CO_2 glass processing machine has been developed.



- **Direct-written short-wavelength Fiber Bragg Gratings (FBGs)** in silicate and soft-glass fibers using a femtosecond laser. These gratings are more challenging than those used in optical communications or for sensing because of the much shorter wavelength. A special recipe using the "Line-by-Line" technique and high Bragg orders (4-10) has been developed for silicate fibers, starting from the Output Coupler (OC) because of its lower reflectivity.

Future work

- Further experimental validation of the Matlab programs.
- Development of FBG fabrication recipe for the High-Reflectivity (HR) mirror.
- FBG inscription directly on the soft-glass active fiber.
- Optimization of the active medium cooling, especially for the DPSS case.
- Studies on the long-term stability of silica-soft glass splices.

List of attended classes

- 01TUFRV- All you need to know about research data management and open (12/04/2022,3)
- 01SHMRV– Entrepreneurial Finance (02/09/2022,1)
- 01UNTRV – Managing conflict: negotiation and communication (18/03/2022, 1)
- 08IXTRV – Project management (31/08/2022, 1)
- 01RISRP – Public speaking (07/10/2021, 1)
- 01SWPRV – Time management (06/03/2022, 1)
- 02LCPRV- Experimental modelling: construction of models from experimental data (24/05/2021,7)
- 01DOMKG- Introduzione all'ottica ed alle Tecnologie quantistiche (05/05/2022,5)
- 1MMRRV- Tecniche numeriche avanzate per l'analisi ed il progetto di antenne (09/06/2021,4)

Politecnico di Torino

PhD program in
Electrical, Electronics and Communications Engineering