MARIE SKŁODOWSKA-CURIE POSTDOCTORAL FELLOWSHIPS 2025

EXPRESSION OF INTEREST FOR HOSTING MARIE CURIE FELLOWS

HOST INSTITUTION

Physics department, FCT, NOVA University Lisbon

RESEARCH GROUP AND URL

Solar-pumped lasers group, https://www.cefitec.fct.unl.pt/lasers

SUPERVISOR (NAME AND E-MAIL)

Dawei Liang (dl@fct.unl.pt)

SHORT CV OF THE SUPERVISOR

Dr. Dawei Liang is Associate Professor with Habilitation of the Physics Department of the NOVA University of Lisbon. He obtained his B.S. and MSc. degrees from Tianjin University in precision instruments in 1984 and 1986, respectively. He obtained his Ph.D. degree in optoelectronics from Chongqing University in 1991. He obtained an Equivalent Ph.D. degree in optoelectronics and microelectronics from NOVA University Lisbon in 1995. He initiated his academic and pedagogic career, as Invited Assistant Professor in 1991, Assistant Professor with Tenure in 1996, Associate Professor with Tenure in 2020, Associate Professor with Habilitation in Physics Department of NOVA University in 2023. He presently serves as a member of the physics department board and Ph.D. program board.

Dawei Liang was the supervisor of seven and co-supervisor of four Ph.D. candidates on solar-pumped lasers. He accomplished one postdoctoral researcher orientation and is presently involved in two ongoing FCT junior researchers mentoring activities. He has also supervised nearly forty MSc. students through his academic career. He accomplished two fiber optic impact sensor projects for Strathclyde University, United Kingdom in 1991 and 1992. He initiated optical fiber laser diode stack beam shaping project for thin-disk lasers for Stuttgart University, Germany in 2009. He was also the principal researcher for eleven transitional access solar laser projects within the framework of Solar Facilities of European Research Area (SFERA 1-SFERA2-SFERA 3, RISEnergy) EU projects during 2011-2025. He was the principal researcher of three Portuguese FCT-MCTES research projects.
In the last ten years, he has published 75 research articles, as indexed by Scopus. He was invited to review 182 manuscripts by 65 scientific journals. He is Associate Editor of “Journal of Photonics for Energy”, Editorial board member of “International Journal of Electrical and Electronic Engineering and Telecommunications”, “Academia Green Energy”, “Clean Energy and Sustainability”, “Energy Research Journal”, and Editor of “Physical Science & Biophysics” Besides, he also serves as Guest Editor of “Energies”, “Sustainability”, and Topical Advisory Panel Member of “Photonics”.

Dawei Liang was the founder of the solar-pumped laser laboratory of the Physics Department of NOVA University. He leads presently NOVA laser technology research team of CEFITEC. His NOVA solar laser laboratory was established more than a decade ago to further boost both solar-to-laser conversion efficiency and beam quality of the state-of-the-art solar-pumped lasers. The laboratory holds world records in solar laser collection efficiency of 41.3 W/m2 and solar-to-laser conversion efficiency of 4.64%.

research on solar lasers were highlighted or featured by Laser Focus World in 2013, 2016 and 2022, Journal of Photonics for Energy in 2019-2022, and SPIE News in 2022. He was among

“World’s Top 2% Scientists list” by Stanford University in 2021, 2023 and 2024. He published a first and corresponding author Springer Nature textbook on “Solar-Pumped Lasers” in March 2023.

5 SELECTED PUBLICATIONS

- **Dawei Liang***, Joana Almeida, Miguel Catela, Hugo Costa, Dário Garcia, Bruno D. Tibúrcio, Emmanuel Guillot, and Cláudia R. Vistas “Lowest threshold solar-pumped Ce:Nd:YAG laser with 2.06% solar-to-TEM00 mode laser conversion efficiency” **Solar Energy Materials and Solar Cells**, 270, **2024**, 112817 (5 Citations), (FWCI 1.92) https://www.sciencedirect.com/science/article/pii/S0927024824001296
- **Dawei Liang***, Cláudia R. Vistas, Dário Garcia, Bruno D. Tibúrcio, Miguel Catela, Hugo Costa, Emmanuel Guillot, and Joana Almeida “Most efficient simultaneous solar laser emissions from three Ce:Nd:YAG rods within a single pump cavity” Solar Energy Materials and Solar Cells, 246, 2022, 111921 (42 Citations), (FWCI 3.50) https://doi.org/10.1016/j.solmat.2022.111921
- **Dawei Liang***, Cláudia R. Vistas, Bruno D. Tibúrcio, and Joana Almeida “Solar-pumped Cr:Nd:YAG ceramic laser with 6.7% slope efficiency” Solar Energy Materials and Solar Cells, 185, 2018, Pages 75-79 (70 Citations), (FWCI 2.05) https://doi.org/10.1016/j.solmat.2018.05.020
- **Dawei Liang***, Joana Almeida, Cláudia R. Vistas, and Emmanuel Guillot, “Solar-pumped Nd:YAG laser with 31.5W/m2 multimode and 7.9W/m2 TEM00-mode collection efficiencies” Solar Energy Materials and Solar Cells, 159, 2017, Pages 435-439 (89 Citations), (FWCI 2.86) https://doi.org/10.1016/j.solmat.2016.09.048
- **Dawei Liang*** and Joana Almeida, "Highly efficient solar-pumped Nd:YAG laser," Optics Express, 19, 26399-26405, 2011. (126 Citations), (FWCI 2.71) https://doi.org/10.1364/OE.19.026399

PROJECT TITLE AND SHORT DESCRIPTION

Pulsed solar-pumped Ce:Nd:YAG lasers for efficient and rapid hydrogen extraction from aqueous ammonia under ambient condition without catalyst

Hydrogen (H2), the cleanest energy source and an important industrial material, is one of the foundations of future society. H2 presents a high caloric value and generates much higher energy compared to conventional fuels. Other H2 properties, such as high diffusivity, wide range of flammability, low ignition energy and high flame speed, or a high-ignition temperature, make this fuel very attractive, but at the same time quite challenging to work with. Thus, H2 is flammable, explosive, and inconvenient for transport. Therefore, in situ H2 production is an effective way to solve this problem. Ammonia (NH3) is an excellent source of H2 in its liquid form, containing twice as much H2 as liquid H2 by volume. Liquid ammonia can be stored and transported in large tanks at room temperature and is safer than propane and as safe as gasoline. Aqueous ammonia is a promising liquid H2 carrier and can be widely used for H2 production. However, the H2 extracted from ammonia−water presents considerable challenges. The conditions for H2 extraction through traditional thermal catalytic decomposition are harsh as the process requires a continuous external heat supply. Other methods of extracting H2 from ammonia require complex catalysts, which contain expensive precious metals. Although various methods have been developed to improve the efficiency of H2 extraction from aqueous ammonia, they are still far from practical industrial applications. Therefore, it is very important to develop new methods enabling the efficient extraction of H2 from ammonia. In January, 2024, Yan et al. reported a simple and highly efficient method for H2 extraction from aqueous ammonia by laser bubbling in liquids at room temperature and ambient pressure without catalyst. A maximum apparent yield of 33.7 mmol/h was realized, which was far higher than that by most H2 evolution reactions from aqueous ammonia under ambient conditions. However, this excellent result was obtained by using a Spectra-Physics Quanta-Ray pulsed lamp-pumped Nd:YAG laser with very low (less than 0.4%) electrical-to-TEM00 mode (M2 ≤ 1.5) laser power conversion efficiency. Economically, its high budget (about 100 kEuros for a Quanta-Ray PRO-350 laser) and electrical energy consumption (8.75 kW), could prevent its practical use for clean energy transition. Highly motivated by the success in lamp-pumped laser H2 extraction, we present here a novel research plan for hosting MSCA postdoctorates: "Most efficient and rapid H2 extraction from aqueous ammonia under ambient condition by a pulsed seven-beam solar-pumped Ce:Nd:YAG laser".

Firstly, we will concentrate on producing the first 150 W continuous-wave (cw) multimode Ce:Nd:YAG solar laser emissions with 84.0 W/m2 collection efficiency. The heliostat plane mirror of NOVA University will reflect sunlight towards an indoor laboratory, where a stationary parabolic mirror with 1.73 m2 effective collection area will be used to collect and concentrate incoming solar power for the efficient pumping of seven thin Ce:Nd:YAG rods. More importantly, nearly 90 W cw TEM00 mode ($M2 \leq 1.3$) total solar laser power is feasible to be obtained experimentally, corresponding to an unprecedented 50.5 W/m2 TEM00 mode collection efficiency.

Secondly, the seven-beam cw Ce:Nd:YAG solar laser will be operated in Q-switch regime and its 1064 nm fundamental wavelength of emission will be frequency-doubled to deliver 532 nm green laser radiation. Our objectives include: (1) Q-switching of the NOVA cw solar lasers such to deliver high-energy laser pulses at 1064 nm with good beam quality (TEM00 transverse distribution); (2) Second harmonic generation from 1064 nm Q-switched solar lasers to yield pulsed laser radiation at 532 nm in TEM00 transverse mode distribution. With the 1.73 m2 effective collection area parabolic mirror of NOVA University, seven series of solar laser pulses, each with 1.5 mJ-class energy, about 30 ns width and up to 10 kHz-class repetition rate, will be produced, resulting in 7×15 J = 105 J total pulse energy per second, being 21 times higher than that by the Quanta-Ray lamp-pumped Nd:YAG laser with 8.75 kW electrical power supply.

We will use seven optical fibers to transmit the Q-switched TEM00 mode 532nm green laser pulses from the Ce:Nd:YAG laser head to seven fused silica reactors filled with ammonia-water solutions. When the laser pulses applied to aqueous ammonia, the molecules at the focus point will be excited and ionized to produce cavitation bubbles with abundant energetic and active particles inside. These active particles will interact with each other rapidly to produce H2.

Besides, powered by free sunlight, our pulsed seven-beam Ce:Nd:YAG solar lasers will be both most efficient in operation and effective in cost. Many lamp-pumped, as well as diode-pumped solid-state lasers installed in European industries could be, most hopefully, replaced by solar lasers. Factories with laser material processing need like laser welding, surface treatment (hardening, glazing, alloying, or cladding), laser removal (hole drilling, cutting, or marking), laser electronic component fabrication etc. may consider installing our sun-powered lasers to accomplish these tasks. Factories with environmentally friendly infrastructure, equipped pulsed seven-beam solar lasers, could replace the classical laser equipment with huge electrical energy consumption, ensuring effective clean energy transition and avoiding greenhouse emission.

The Council of the European Union (EU) has adopted legislation providing H2 charging stations every 200 km. Member States shall also ensure that H2 charging stations are installed along the ten-core network at least every 200 km by 2031. A future H2 pilot charging station (where H2 can be extracted locally from aqueous ammonia by our pulsed solar lasers), can be planned for charging H2 vehicles. The risk of H2 transport can hence be eliminated, and this action may serve as a good example for more in situ H2 charging stations in EU countries, which will largely strengthen the outcomes of our research plan, triggering enormous social and economic impacts.

SCIENTIFIC AREA WHERE THE PROJECT FITS BEST*

Physics (PHY)