X-ray absorption spectroscopy (XAS) for high performance rare-earth-doped fiber lasers

THE INDUSTRIAL CHALLENGE

NKT Photonics is a world leading manufacturer of fiber lasers. Understanding how the production of fiber lasers affects the local environment of the lasing ion is essential for developing and optimizing the wall-plug efficiency and lifetime of fiber lasers. The efficiency of a fiber laser is directly dependent on the concentration of the lasing ion, which though with increasing concentration tend to cluster. Thus, understanding the local chemical structure around the lasing ion, more specifically the distance between the lasing ions is of high interest.

For this purpose, a number of research questions was specified that could aid the development of high-performance fiber lasers. The primary objective was to observe whether there was any clustering of lasing ions in the fiber lasers.

WHY USING A LARGE-SCALE FACILITY

The low concentration of the lasing ion and the complex glassy structure of the fiber material makes synchrotron-based XAS a unique tool for studying the local environment of the lasing ion. The *Extended X-ray Absorption Fine Structure* (EXAFS) was of primary interest for the objectives in the project, since it reveals information about coordination and distances but *X-ray Absorption Near Edge Structure* (XANES) was also of interest in order to get information about the oxidation state.

HOW THE WORK WAS DONE

Preforms were industrially manufactured using modified chemical vapour deposition (MCVD) and then drawn into fibers. Eight samples of both preforms and fibers were prepared with same variation of compositions. The samples were measured at the Balder beamline at MAX IV, together with high purity reference materials. The sample thickness of about 4 mm was optimized to be measured directly in the beamline without further sample preparation. Both the EXAFS- and the XANES spectra were acquired in fluorescence mode for rare earth L_3 edge. We thank Kajsa Sigfridsson Klaus at Balder, MAX IV, for her help.

All measured data were processed in Athena and the EXAFS function were modelled using Artemis and FEFF9. Also, a new python-based approach was developed that gives increased control of the challenging fitting process of complex materials, such as glass.

THE RESULTS AND EXPECTED IMPACT

The EXAFS results confirmed that no significant clustering of lasing ions was present. It could also reveal that the lasing ion is present in a distorted coordination environment and that the structure is concentration-dependent. The structural analysis has given that there are multiple structures that are mixed around the lasing ion. The EXAFS-results also revealed a significant difference of the local chemical environment in fibers compared to preform, which in hypothesis is due to diffusive movement of ions during the drawing of fibers.

XANES revealed that the oxidation state is primarily RE^{3+}, with no significant signs of RE^{2+}.

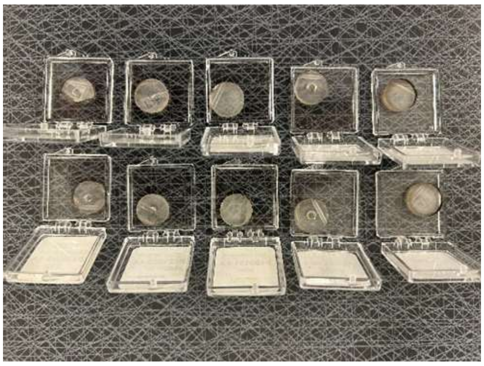

Figure. A photo of the set of preforms that were prepared for the XAS study.

"To be able to study the local chemical structure of the lasing ion has been interesting but challenging" ***/Lars Norin, NKT Photonics***

Contacts: Lars Norin, NKT Photonics AB, lars.norin@nktphotonics.com
Jenny Rissler, LSRI-expert, Lund University, jenny.rissler@design.lth.se

Vinnova's project No: 2023-02803 **Duration:** November 2023 -- March 2026

Funded by Sweden's Innovation Agency, Vinnova, in order to build competence and capacity regarding industrial utilisation of large-scale research infrastructures such as MAX IV and ESS.