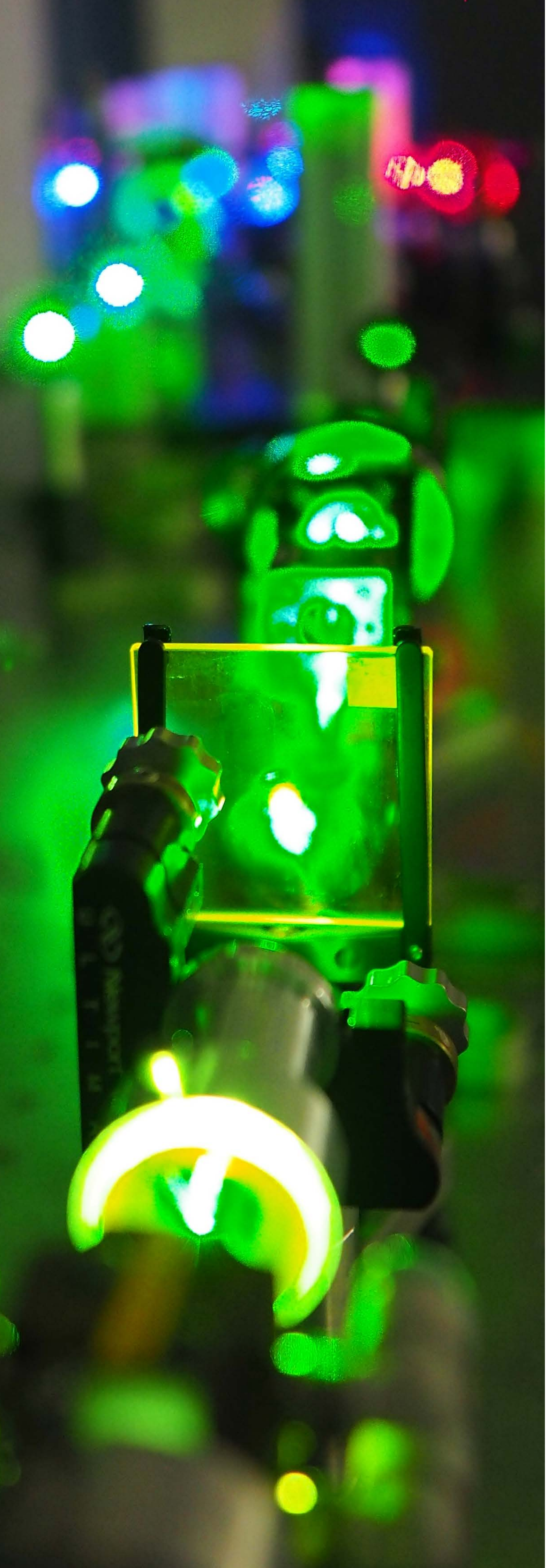
Center for Laser Materials

ikz LEIBNIZ-INSTITUT FÜR KRISTALLZÜCHTUNG



CRYSTALS FOR ADVANCED SOLID-STATE LASER TECHNOLOGY

Solid-state lasers are a key technology in our modern society. They are the basis of numerous applications and have transformed the way we live, work and communicate. They are used in materials processing, medicine, communication, scientific research, entertainment and many other fields and their range of applications continues to expand as new technologies and materials are developed.

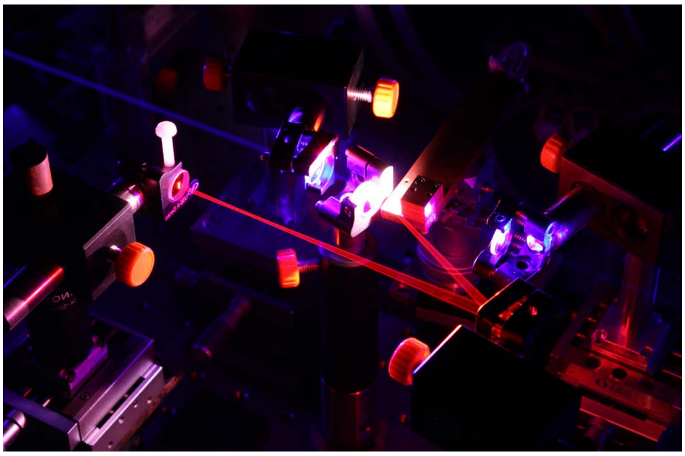
Garnets, including the widely known YAG ($Y_3Al_5O_{12}$) are the most famous class of host materials and suitable for a variety of applications. Doped with Yb^{3+} they enable to reach kW of output power in diffraction limited beam quality at wavelengths around 1.03 µm. Tm^{3+}-doped YAG is a quite mature solid-state laser gain material for the 2 µm range. However, when it comes to lasers operating at even longer wavelengths in the mid-infrared spectral range around 3 µm, e.g. based on Er^{3+}-doping, materials with lower phonon energies are often a better choice to facilitate efficient laser emission. On the other hand, for lasers with direct emission in the visible, a low crystal field strength and a high band-gap energy are required to prevent undesired loss processes. When it comes to solid-state lasers emitting high energetic or short pulses, other materials properties such as the upper state lifetime or the emission bandwidth become relevant.

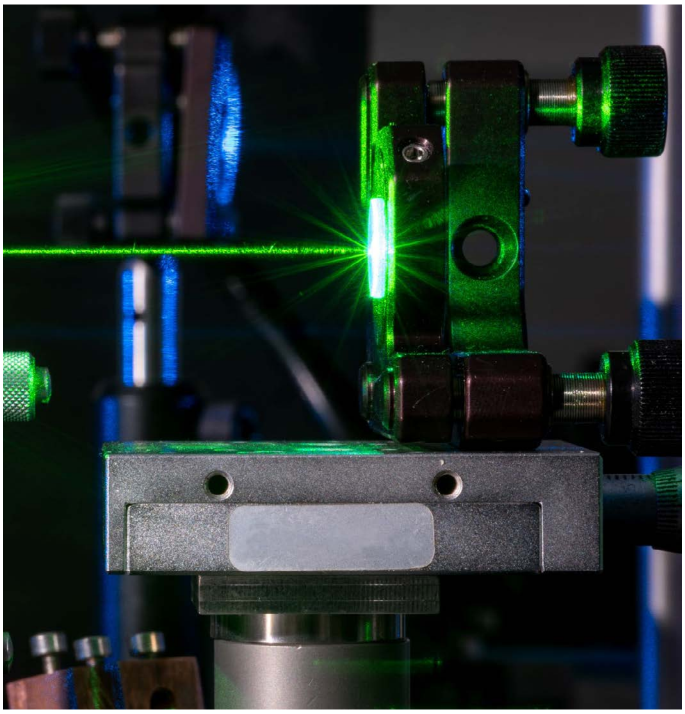
Besides the choice of a proper gain material, also its availability in high optical quality and sufficient dimensions is crucial for any solid-state laser. The vast majority of laser crystals such as, for example, YAG and YVO_4 are grown by the Czochralski-method. Other important materials like the tungstate crystal KYW ($KY(WO_4)_2$) cannot be directly grown from a congruent melt and solution growth is required, which increases the price as well as the variations of specimens provided by different suppliers. Last, but not least, fluoride host crystals, well suited for mid-infrared and visible lasers, require a sophisticated preparation of the starting materials and growth under protective atmosphere to avoid oxide and hydroxide impurities.

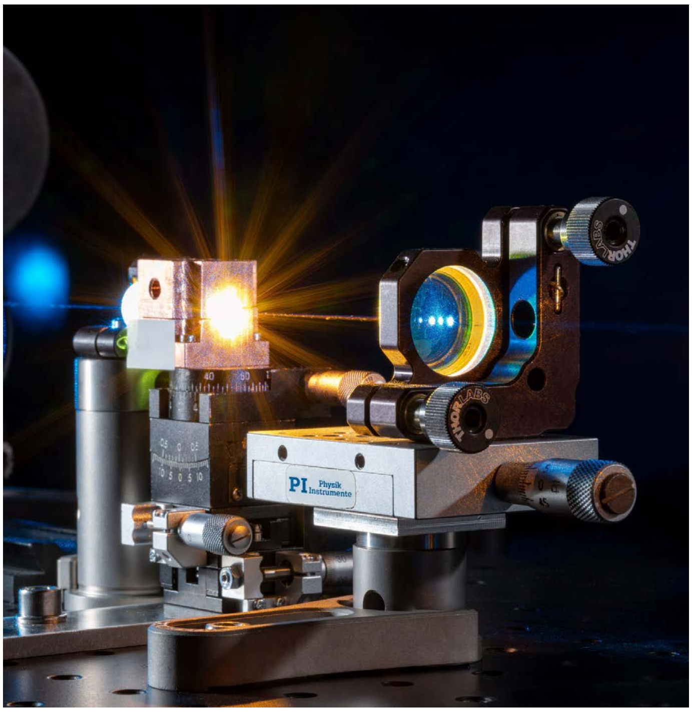
The researchers at the Center for Laser Materials (ZLM) at the Leibniz-Institut für Kristallzüchtung (IKZ) have a longstanding expertise in these questions. We are ready to support you in design & development, quality control & troubleshooting as well as training & education in all fields of solid-state lasers. We are also equipped to provide and qualify prototype crystals and small series of crystalline laser materials tailored to your application. Our work helps you to improve the performance of your laser system to achieve the desired performance.

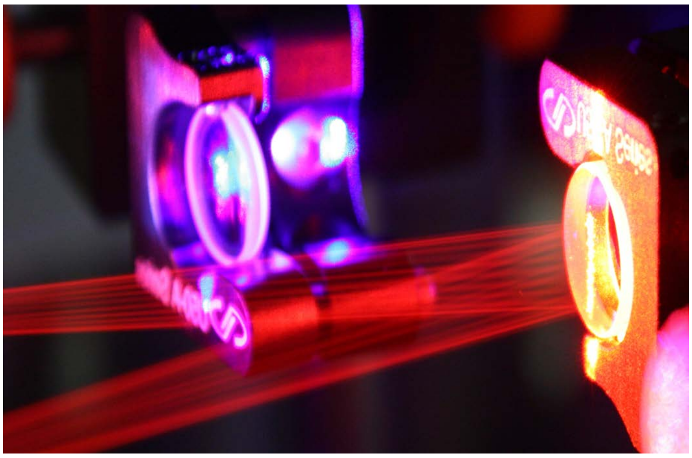
If you are interested in our research and services, please contact us:

Dr. Maike Schröder
Strategic Science Management
Phone +49 30 6392 3008
E-Mail maike.schroeder@ikz-berlin.de









WHO WE ARE

The Center for Laser Materials is a research unit at the Leibniz-Institut für Kristallzüchtung and dedicated to research and qualification of crystalline materials for optical applications. To this end we use our state-of-the-art laser and spectroscopy laboratories as well as the interdisciplinary research infrastructure at the IKZ.

The Center for Laser Materials serves as international one-stop shop for partners from research and industry for optical crystals for laser applications, optical isolators or non-linear frequency conversion.

Our research covers the whole value chain of optical materials from the growth of laser crystals, the characterization of gain materials as well as the evaluation of the laser performance.

Our main focus lies on rare earth and transition metal doped oxide and fluoride crystals.

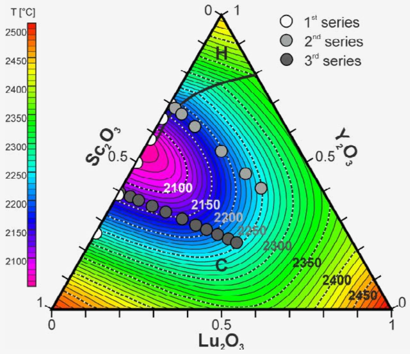
We strive for improving the performance of existing laser materials and investigating new compositions that may open up new wavelength ranges, and enable more efficient laser operation, shorter pulse durations or higher output power. The large variety of in-house available characterization techniques supports this ambition by enabling short feedback loops from the material evaluation back into the growth-process.

Together with our scientists, research partners and industrial collaborators, we identify and secure potential innovations and stimulate and accompany their commercial exploitation. We also provide feasibility studies and expert opinions on material science topics. In addition, we are also offering individual workshops and training courses on demand.

FIELDS OF RESEARCH

CRYSTAL GROWTH OF OXIDE CRYSTALS

In collaboration with the crystal growth department at IKZ, we develop and explore new optical materials. For example, sesquioxides are outstanding host materials for rare-earth doped solid-state lasers. Due to their high melting temperatures, the fabrication of large crystals with high optical quality remains a challenge. We have approached this by investigating the ternary phase diagram of the high melting sesquioxides Lu_2O_3, Sc_2O_3 and Y_2O_3 and determined compositional ranges with melting points low enough to allow for the growth of high-quality rare-earth doped sesquioxides by the well-established Czochralski method from iridium crucibles.



C. Kränkel et al.: Czochralski growth of mixed cubic sesquioxide crystals in the ternary system Lu_2O_3-Sc_2O_3-Y_2O_3; Acta Cryst. B, B77 (4) 550-558 (2021), https://doi.org/10.1107/S2052520621005321

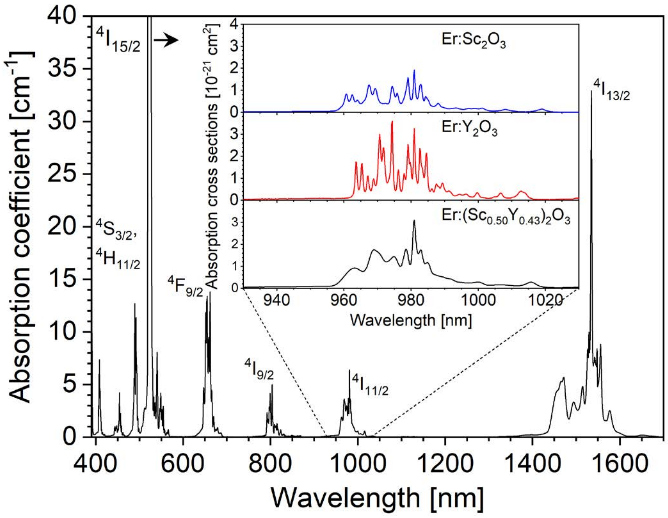
VISIBLE LASERS

In the development of solid-state lasers with emission in the visible spectral range based on Pr^{3+} and Tb^{3+}, researchers at the ZLM played a pivotal role. We develop novel and efficient diode-pumped solid-state lasers with emission in the green and in the yellow spectral range, well within the so called „green gap“ at wavelengths between 540 nm and 600 nm not accessible to semiconductor lasers.


H. Tanaka et al: Visible solid-state lasers based on Pr^{3+} and Tb^{3+}; Prog. Quantum Electron. 84, 100411 (2022) https://doi.org/10.1016/j.pquantelec.2022.100411

INFRARED LASERS

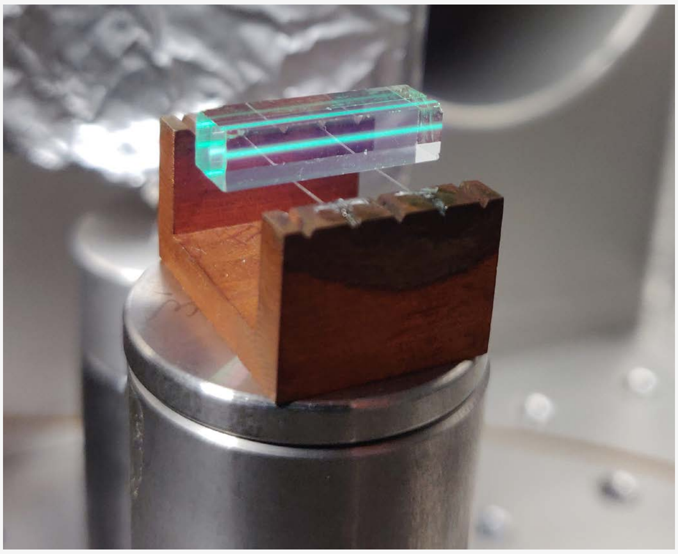
The ZLM has a longstanding expertise in the characterization of rare-earth doped mixed sesquioxides for highly efficient infrared lasers. We have achieved significant progress in the field of mixed cubic sesquioxide crystals as host materials for solid-state lasers based on the rare-earth ions Yb^{3+}, Tm^{3+}, Er^{3+}, and Ho^{3+} in the 1 µm, 2 µm and 3 µm spectral range in continuous-wave and mode-locked operation mode.



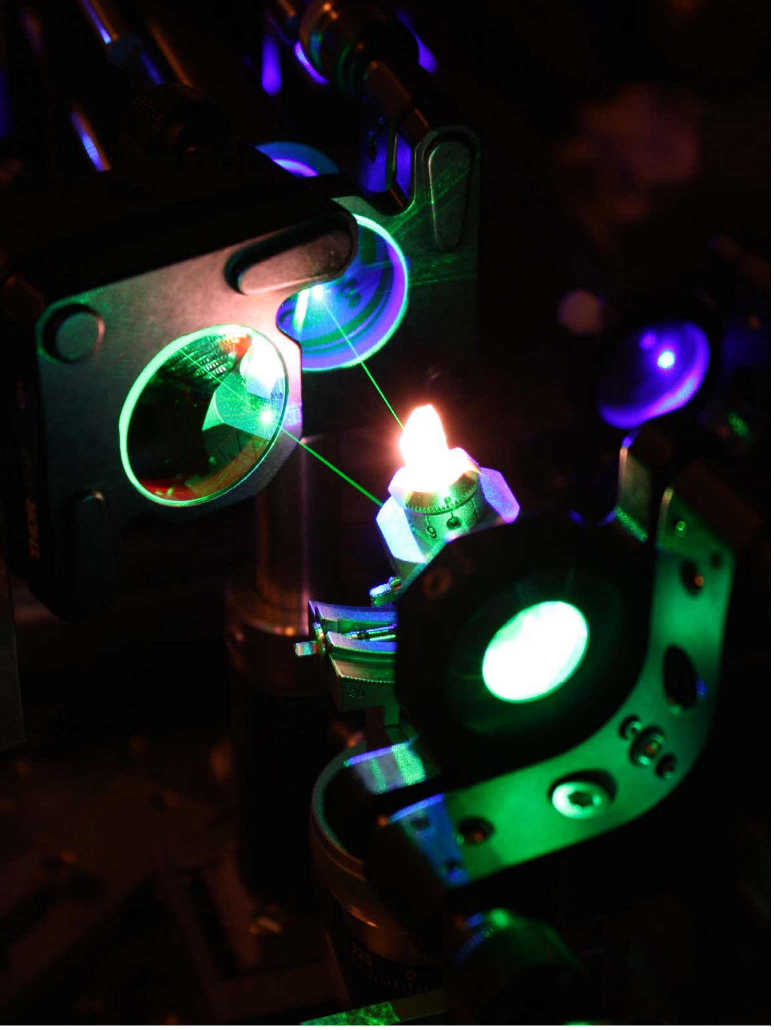
C. Kränkel et al: Rare-earth doped mixed sesquioxides for ultrafast lasers; Opt. Mat. Express 12 (3), 1074-1091 (2022) https://doi.org/10.1364/OME.450203

LASER COOLING AND FLUORIDE CRYSTALS

Fluoride host materials are highly interesting host materials for solid-state lasers, but their unusual crystal field also allows to cool Yb^{3+}-doped fluorides by irradiation with light at wavelengths longer than the average fluorescence photon wavelength and successive anti-Stokes fluorescence to temperatures below 100 K. We investigate fluoride materials like $Yb:CaF_2$ and $Yb:SrF_2$ and introduce them as novel materials for solid-state laser cooling.



S. Püschel et al.: Solid-state laser cooling in $Yb:CaF_2$ and $Yb:SrF_2$ by anti-Stokes fluorescence; Opt. Lett. 47 (2), 333-336 (2022), https://doi.org/10.1364/OL.449115



OUR SERVICES

CRYSTAL GROWTH OF LASER MATERIALS

Making use of IKZ's world-leading expertise in the field of semiconductor and isolator crystal growth, the Center for Laser Materials is your partner for tailored solutions for laser applications. This includes the growth of oxide host materials with individual doping ions and concentrations. The IKZ has also a longstanding expertise in the growth of fluoride materials including a closed process chain preventing oxide or hydroxide impurities often found in fluorides.

Our scientific growth approach moreover facilitates the growth of crystals with unprecedented purity levels by using highly pure starting materials allowing for increased damage thresholds or improved UV transparency. Located in the heart of Europe, we also contribute to the technology sovereignty of your application.

The development of new devices for future technologies does not only require high-quality crystalline materials with tailored properties, but also their reliable availability. Our aim is thus to go beyond the academic level by offering small-scale series of optical crystals with reproducible properties to enable our partners to develop new technologies or devices based on these materials.

To hand over high quality crystal solutions to optical component and system manufacturing companies, high precision preparation of optical crystals is a central requirement.

CHARACTERIZATION

The core competence of the Center for Laser Materials lies in the optical characterization of laser gain materials. This includes to perform precisely calibrated and reliable high resolution transmission measurements from the V-UV to the far-infrared spectral range as well as to record fluorescence spectra in the spectral range between 200 nm and 5 µm. Available ns-pulse sources at wavelengths between 0.2 µm and 2.4 µm enable precise determination of the time resolved fluorescence dynamics.

In combination with the chemical analyses available in-house such as x-ray fluorescence (XRF) and atomic emission spectroscopy (ICP-OES) we are able to precisely determine or refine absorption and stimulated emission cross sections of optically active materials required for the conceptual design of lasers and amplifiers.

Our modular spectroscopy setups furthermore enable the development of optical characterization methods tailored to your demands, including pump-probe-spectroscopy, excitation measurements, Z-scan spectroscopy, temperature-dependent measurements at cryogenic or elevated temperatures, and many more.

Besides optical and chemical characterization, we provide further characterization techniques including x-ray crystallography, thermal conductivity measurements, high-resolution microscopy, etc.

These capabilities enable us to provide a full characterization of the optical samples provided by the Center for Laser Materials as well as to detect variations between samples from different charges or suppliers or identify sources of performance degradation.

QUALIFICATION

In our laboratories we provide various excitation sources with diffraction limited beam quality and watt-level output power in the range between 350 nm and 1000 nm, but also at various further wavelengths in the infrared spectral range. In combination with a huge stock of laser mirrors we are thus capable to perform a detailed laser characterization of the continuous wave laser properties of any laser gain material grown at IKZ or provided by our partners. In particular for applications in advanced laser systems such as mode-locked resonators, frequency stabilized resonators, etc., such information is invaluable.

CONSULTATION

The researchers at the Center of Laser Materials combine decades of experience in the field of solid-state lasers and related crystal growth and spectroscopy. We can provide our independent technical consultancy in many fields from basic feasibility studies over the choice of the doping ion and host material for your desired application to the proper composition and purity of the final gain material and related trouble shooting. We also provide workshops and staff training on demand.

THE LEIBNIZ-INSTITUT FÜR KRISTALLZÜCHTUNG IKZ

The Leibniz-Institut für Kristallzüchtung (IKZ) in Berlin-Adlershof is an international state-of-the-art competence center for science & technology as well as service & transfer for innovations in and by crystalline materials. The R&D spectrum thereby ranges from basic over applied research activities up to pre-industrial research tasks.

Crystalline materials are key technology enabling components to provide electronic and photonic solutions to today´s and future challenges in society such as artificial intelligence (communication, mobility etc.), energy (renewable energies, power conversion etc.) and health (medical diagnosis, modern surgical instruments etc.). The IKZ provides innovations in crystalline materials on account of its combined in-house expertise on plant engineering, numerical simulation and crystal growth, enabling it to achieve highest-quality crystalline materials with tailored properties.

Nanostructures, thin films and volume crystals are investigated, the latter being the unique selling point of the institute. Cutting-edge theoretical and experimental materials science know-how is a strong asset for IKZ´s R&D activities.

Together with partners from institutes, with technology platforms as well as industry companies, the institute also drives innovation by crystalline materials, namely the reliable evaluation and benchmarking of innovative crystalline prototype materials for disruptive technology approaches.

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ikz LEIBNIZ-INSTITUT FÜR KRISTALLZÜCHTUNG

Max-Born-Str. 2
12489 Berlin
Germany

Phone +49 30 6392 3001
E-Mail cryst@ikz-berlin.de

www.ikz-berlin.de