Ultra-long lasers challenge conventional knowledge about laser technology

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The EU ULTRALASER project is proving that lasers can be more than just sources of coherent light. With the right configuration, they can also serve as a transmission medium – a development that opens the door to an array of new uses.

Thanks in part to advances in material science, technology and underlying physics, today lasers have become ubiquitous devices used across a range of sectors – including fundamental science, manufacturing, engineering, telecommunications and medicine. Continuing along this trajectory of advancement in laser technology, the ULTRALASER project is focusing on the development of ultra-long lasers, or lasers with a cavity formed by a long (up to hundreds of kilometres) span of optical fibre transformed into amplifying medium by the Raman effect.

Ultra-long lasers are challenging the conventional view of lasers as being just sources of coherent light. According to ULTRALASER researchers, when an ultra-long laser cavity implemented in optical fibre is used, the laser can function not only as a source of coherent light, but also as a transmission medium.

'Such an ultra-long resonator, which can have a length scale of several hundreds of kilometres, is not only an exciting new physical system, but could lead to a radical new outlook on the transmission of information and secure communications,' says the project's Principal Investigator Sergei Turitsyn. He notes that such lasers with extended resonators and the closely related distributed feedback random fibre laser systems will likely have applications in such fields as telecommunications, spectroscopy, global positioning systems, material processing and bio-medical imaging.

A new enabling technology

ULTRALASER developed a new architecture comprised of random distributed feedback lasers capable of exploiting multiple Rayleigh scattering (the scattering of light on inhomogeneities in an optical fibre medium). This process, combined with distributed Raman amplification, was used to produce feedback and lasing in long fibre.

'We believe the amplification technique based on ultra-long fibre lasers could be a new enabling technology for transmission with very long amplification spans,' notes Turitsyn. 'Even more exciting, this 'quasi-lossless' fibre medium will likely have interesting applications in all-optical nonlinear data processing.' According to Turitsyn, this advancement will open up methods for the design of photonic devices based on a mathematical theory of integrable nonlinear systems, with functionalities that cannot be achieved in linear optical devices. 'This research is directly relevant to increasing capacity of optical communication systems,' he says.

In addition, the project has explored new architectures of model-locked lasers, including isolator-free cavities and various gain fibres to support generation in the 1 – 2 micron wavelength range. Project researchers also discovered a new mechanism of spontaneous pattern formation in fibre lasers that results from the periodic zig-zag modulation of losses for different spectral components.

According to Turitsyn, this discovery is important for creating a new generation of efficient pulsed fibre lasers that are used in various applications. 'Our research has led to the development of new measurements and signal processing techniques for characterising partially mode-locked and stochastic generation and uncovering the complex intra-cavity dynamics of radiation with localised structures,' he says. 'The project has advanced the science and technology of lasers featuring extended cavity length.'

Advancing physics and opening doors

Clearly, the ULTRALASER project has made significant contributions to the understanding of the underlying physics of ultra-long fibre lasers and the non-linear physics behind conventional fibre lasers. 'We have developed new engineering technologies and explored emerging research and technology applications,' explains Turitsyn. 'Overall, the project advanced the physics underlying the operation of fibre lasers and has revealed new opportunities and directions in high-speed fibre communications, secure communications and laser physics – among other scientific and technology-related fields.'

But the work doesn't stop here. As a result of these initial breakthroughs, Turitsyn was awarded a follow-up proof-of-principle grant for the commercialisation and knowledge transfer of the project's key technology and architecture. So stay tuned for a demonstration of a commercial prototype featuring advanced parameters in the near future.

More information: Project page: cordis.europa.eu/project/rcn/98258_en.html

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