

VERSATILE INFRARED LASER SOURCE FOR LOW-COST ANALYSIS OF GAS EMISSIONS



FINAL EXECUTIVE SUMMARY



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Project acronym & number: VILLAGE – 034010

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Contract Type: Specific Targeted Research Project

Consortium members:

Participant name	Short name	Country
Thales Research & Technology (Coordinator)	TRT	France
Norsk Elektro Optikk	NEO	Norway
Heinrich-Heine Universität Düsseldorf	HHUD	Germany
University of Southampton	ORC	United Kingdom
Universidad de Valladolid	UVA	Spain

Dissemination level for present deliverable: PU

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Project web site: <http://www.neo.no/village/>.

Recent demonstrations of tunable infrared laser sources based on novel nonlinear optical materials have largely renewed the interest for vibrational molecular spectroscopy. Specific absorption features in the mid-infrared (MIR) range of the spectrum are indeed recognized as a powerful and often unique way to provide high sensitivity detection and identification of a large array of molecules. This is particularly relevant in the gas phase in order to avoid preconditioning steps associated with other detection methods (wet chemistry, gas chromatography, mass spectroscopy). Yet, many promising results have remained confined to laboratories for lack of suitable MIR sources, leaving complex Fourier-Transform spectrometers as the only alternative.

To promote direct MIR spectroscopy as a competitive solution for gas analysis, the main technical and scientific objective of the VILLAGE project is the development of a cost-effective widely tunable MIR laser source of high spectral purity. This source combines a 2 μm Thulium (Tm)-doped fibre laser device including a tunable Bragg grating stage and a nonlinear frequency converting crystal (Orientation-Patterned Gallium Arsenide, OP-GaAs) implemented either in a Difference Frequency Generation (DFG) setup or in a high spectral purity optical parametric oscillator (OPO) cavity as shown in the Figure 1.

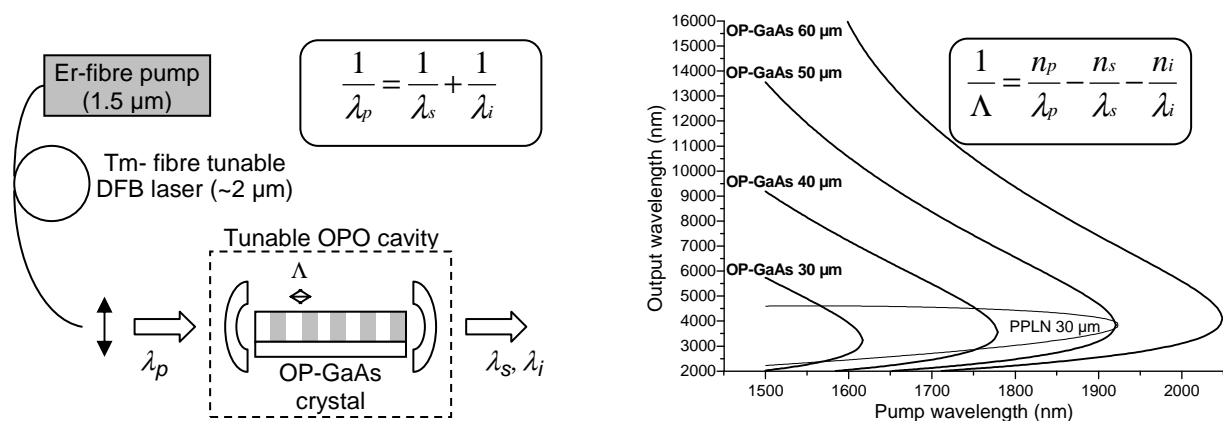


Figure 1 : a) Village source concept (left). b) Typical tuning curves (right).
 Insets : key equations linking pump, signal and idler wavelengths, indices and QPM period.

Such a design has the potential for unprecedented performance in terms of both primary specifications and suitability to target multigas analysis of main pollutants generated by and emitted from industrial processes and more specifically of the gases believed to contribute to global warming.

The project has been supported by the European Commission under the Information Society Technologies priority of the Sixth Framework Program, and involves close collaboration partners from five countries: Thales Research and Technology (TRT, France), acting as the coordinator, Norsk Elektro Optikk (NEO, Norway), the Heinrich Heine University in Düsseldorf (HHUD, Germany), the Optoelectronics Research Centre of the University of Southampton (ORC, United Kingdom) and the University of Valladolid (UVA, Spain).

In agreement with the work plan, the first twelve months of the project have enabled the VILLAGE Consortium to specify and fabricate all the subparts needed to implement a first version of MIR tunable source in order to provide useful feedback to the design of the targeted spectrometer. The corresponding technical achievements thus included:

- The fabrication by ORC of prototype Tm-doped fibres with high thulium concentration and the demonstration of narrow-linewidth Tm-doped DFB fibre lasers at 1935 nm and 1943 nm with output power > 0.3 W, further scaled to ~ 1 W. This has been the highest output power so far reported for a Tm-doped DFB laser operating in this wavelength regime.

- The design, fabrication and delivery by TRT of an OP-GaAs sample exceeding initial expectations in terms of propagation losses and geometrical characteristics, suited to DFG around 8 μm and the microscopic characterizations by UVA of various samples to validate a growth model.
- The selection by NEO of interference-free absorption lines by software supported simulations in the wavelength range from 4 μm to 14 μm .
- The implementation by HHUD of a preliminary DFG experiment around 3 μm and of the planned DFG source around 8 μm .

Building on the knowledge and sub-parts obtained during the first year, an upgraded version of this DFG-based MIR source has been implemented, leading to an exceptional tunability from 7.6 to 8.2 μm (1200 to 1300 cm^{-1}) and to the first spectrometric experiment of the project, demonstrating methane detection. In parallel with such a successful technical achievement, the second year of the project also enabled to model numerous OPO configurations and more precisely assess the main technical options for the final implementation. This led the VILLAGE partners to choose to pursue the OPO development work in HHUD laboratories and to select a DFG design as the preferred solution for the final spectrometer prototype assembled by NEO.

The first of those two options was early identified by the VILLAGE Consortium as the most challenging and reaching the oscillation threshold of a continuous wave OPO based on OP-GaAs has indeed remained elusive to date. Nevertheless, the fruitful collaboration between the partners recently yielded a comprehensive body of both theoretical and experimental results at the state-of-the-art. They demonstrate that the designed OPO cavity, resonating both pump and signal (PR-SRO), is most appropriate to be successful in the targeted experiment in a very near future.

From the industrial point of view, the last period of the project proved rewarding because it was possible in a very limited time to turn the laboratory DFG experiment into a compact MIR source and to validate the potential of this source in a spectrometer prototype, through the monitoring of nitrous oxide around 7.5 μm . This setup has been implemented in a 19 inches rack format in the premises of the SME partner of the project. The latest characterization results make it worth contemplating campaigns of field tests.

The above demonstrations constitute the key achievements of the VILLAGE project and can be further put in perspective with future developments:

- The OP-GaAs crystal is of high interest for several research groups and competitors and may be sold as a stand alone product for a number of spectroscopy-related applications.
- We have demonstrated a DFG-based gas analyzer based on OP-GaAs that is, to the best of our knowledge the first of its kind. Moreover, the spectroscopic measurements using the DFG source have demonstrated that sensitivities achieved are comparable with state-of-the-art gas analyzers based on Quantum Cascade Lasers (QCL).
- The DFG system has proved to operate as expected. Yet, future multi-gas instruments could still benefit from a widely tunable OPO. More work is necessary to demonstrate that CW operation is achievable, but this seems feasible thanks to the developed PR-SRO setup.