P2 PUBLISHABLE PLAN FOR USING AND DISSEMINATING THE KNOWLEDGE

1.1. Exploitable knowledge and its use

The project objectives are actually twofold; they will include a completely new tunable laser source in the Mid IR, which is a product in its own right and is based on several subcomponents also worth exploiting in the long term, and a prototype MIR spectrometer that is specifically designed to be applied in harsh industrial environments and that shows strong prospects for profitable implementation in the mid term. The following table recalls the key characteristics of the corresponding outputs, further detailed in the five next paragraphs:

	Exploitable Knowledge	Exploitable product(s) or measures(s)	Sector(s) of application	Timetable for commercial use	Patents or other IPR protections	Owner & Other Partner(s) involved
1	Tm-doped DFB fiber laser design	Tunable DFB fiber laser	Research laboratories	> 2 years		ORC
2	OP-GaAs growth parameters	Wavelength converters	Research laboratories	3 to 5 years	Licensable know-how	TRT
3	DFG source design	Low-cost MIR tunable source	Spectroscopy	3 to 5 years		HHUD (NEO)
4	OPO source design	MIR tunable source	Spectroscopy	> 5 years		HHUD (NEO)
5	Spectrometer design	Multi-gas monitor	Emission- and process-control	3 to 5 years		NEO (HHUD, ORC, TRT)

Item 1 : Tm-doped DFB fiber laser design

The ORC develops fibre pump sources with performance capabilities that go well beyond the current state-of-the-art. In addition to satisfying the specific needs of this project, these sources will have a huge range of applications in areas such as spectroscopy, differential absorption LIDAR, medicine and even in directed energy laser weapons. The main attractions of these sources from an applications point of view are derived from their narrow-linewidth, flexibility in operating wavelength in the eyesafe wavelength regime and the potential to be scaled to very high-average-powers in both continuous-wave and pulsed modes of operation. Further development of this laser technology is needed before being in a position to start investigating the various exploitation routes that exist outside the area of direct relevance to the Village project.

Item 2 : OP-GaAs growth parameters

TRT is able to ensure small scale production of OP-GaAs crystals. Above that, a preferred solution would be to subcontract the template fabrication and dicing/polishing tasks and license the HVPE growth step. Nevertheless, the process yield remains an issue at this stage of the project.

Item 3 : DFG source design

A narrow-line width mid-IR source based on difference frequency generation (DFG) in orientation-patterned GaAs has been developed in a framework of the VILLAGE project. The DFG source is pumped by a broadly tunable (1540-1570 nm) commercial Er- doped fiber laser system and a custom Tm-doped fiber laser,

developed by ORC. The source can be tuned to any frequency in the 7.6 – 8.2 mm range with an output power of 0.5 mW. A straightforward improvement of the source is an increase of the mid-IR output power by a factor of 3 by AR coating of the crystal facets. The tuning speed of the mid-IR source can be increased to about several cm^{-1} per minute by using commercially available pump lasers with fast mode-hop free tunability. Besides, tuning range of the DFG source can be extended to 6.5 to 15 μm using multi-grating OP-GaAs chips and broadly tunable Tm-doped fiber laser, which is under development in ORC.

A developed OP-GaAs DFG source is an interesting alternative to current cw quantum cascade lasers because of its broad continuous tunability and spectral purity determined by near-IR pump lasers, for which precise wavelength measurement and stabilization techniques are available. Thus, this developed OP-GaAs DFG source is a unique instrument for variety of scientific applications, which rely on high-resolution molecular spectroscopy (e.g. spectroscopy of ultra-cold molecular ions).

The OP-GaAs DFG source has simple construction without moving mechanical parts. Combined with capabilities of pumping fiber lasers, it allows developing very robust and compact turnkey device for field applications. For instance, it can be a part of mobile gas spectrometer for express on-the-site analysis of gas emissions. With the exception of OP-GaAs crystal, the construction of this OP-GaAs DFG source is pretty standard, although it includes some custom components (a prism which allow very efficient separation of high-power pump lasers emission from relatively weak mid-IR output) which may be the subject of IP protection. However, the IP is mostly concentrated in the DFG source's firmware from NEO: techniques, algorithms and code for control, wavelength tuning, and conversion of raw signals to valuable spectroscopic data.

HHUD has already successfully transferred technology to a SME: it licensed its cw-OPO invention, after protection by a European and a US patent, to a German company, now producing cw-OPOs in the 1.5 to 3.5 μm spectral range, for research laboratory use. With this background, HHUD is very aware of the need to protect IP and to stimulate companies working in diverse application fields. HHUD thus can be helpful in establishing direct links between NEO and third parties, as well as open up new directions of research and application of the GaAs sources.

Item 4 : OPO source design

The VILLAGE consortium recently calculated that reaching the oscillation threshold of a CW OPO would prove challenging. Even if the promises of this option in terms of power and tunability definitely make it worth pursuing tunable CW DFG was chosen as the preferred option to build the final spectrometer. Exploitation prospects for the OPO solution will therefore be reviewed during Year 3.

Item 5 : Spectrometer design

In-situ measurements of sulfur dioxide (SO_2) at high temperatures (> 1300K) in refineries and recycling facilities for industrial waste are a huge market with many potential customers, but up to now there is no laser based industrial product available able to measure this gas due to an absence of suitable absorption lines in the near-infrared. A spectrometer based on a difference-frequency laser with a tuning range from 7.6 μm to 8.2 μm would allow to address interference free absorption lines of SO_2.

After a successful field test the DFG prototype would have to be developed further to meet the requirements necessary for an industrial, maintenance-free instrument. A final product would involve HHUD (DFG system design), ORC (Tm fiber laser), and TRT (OP-GaAs crystal growth). Thus further collaboration after the end of the project would be necessary. At the moment it is open how such a collaboration could look like. However, after successful tests with a prototype it would suggest itself that the VILLAGE consortium starts a discussion about a new collaboration, potentially involving new participants, either technology providers or end-users. For a commercialization a period of three to five years has to be scheduled.

1.2. Dissemination of knowledge

During the last twelve months all VILLAGE partners have disseminated significant research results at international and national conferences as well as in referenced research journals. The following table presents those publications and communications for period P2 as well as planned activities for the third year.

	Planned/ Actual Date	Type	Type of audience	Countries addressed	Size of audience	Partner involved
1	09/2007	Conference/ Exhibition	Research/Industry	Europe	100	NEO
2	09/2007	Poster	Research	Europe	300	HHUD
3	09/2007	Conference	Research	All	500	ORC
4	03/2008	Poster	Research	Germany	2000	HHUD
5	05/2008	Oral presentation	Research	All	2000	ORC
6	05/2008	Poster	Research	All	100	HHUD
7	07/2008	Poster	Research	All	300	HHUD
8	07/2008	Publication	Research	All		HHUD/ORC/TRT
9	(2008)	Publication	Research	All		ORC
10	(2008)	Oral presentation	Research	All	300	TRT/UVA
11	(2008)	Poster	Research	All	1000	TRT/UVA

- Item 1 is an event NEO attended as an invited speaker at the “Field Laser Applications in Industry and Research International Conference” (FLAIR 07, Florence, Italy). P. Kaspersen seized the opportunity to promote the first results of VILLAGE to a large audience.
- Item 2 corresponds to a poster presented by S. Schiller during “The 20th Colloquium on High Resolution Molecular Spectroscopy” (HRMS 07, Dijon, France, 3-7 September 2007).
- Item 3 is the accepted paper on the Tm fiber laser work that will be presented at the “Bragg Gratings, Photosensitivity and Poling in Glass Waveguides” (BGPP) OSA meeting in September 2007 in Quebec, Canada.
- Item 4 corresponds to a poster presentation during the Annual Meeting of the German Physical Society, AMOP section (atomic, molecular and plasma physics), 10. - 14. March 2008 in Darmstadt (Poster title: “Tunable mid-IR CW narrowband laser source for molecular spectroscopy “).
- Item 5 is an oral presentation from ORC: Z. Zhang, A. J. Boyland, J. K. Sahu, M. Ibsen and W. A. Clarkson, "Single-Frequency Tm-Doped Fiber Master-Oscillator Power-Amplifier with 10 W Linearly Polarized Output at 1943 nm," Conference on Lasers and Electro-Optics (CLEO 2008), San Jose, USA, 4-9/05/08, paper CFD5.
- Item 6 is a poster presentation from HHUD during a “Workshop on Modern Applications of Trapped Ions”, 18-23 May 2008 in Les Houches, France (Poster title: “Broadly tunable sub-mW CW Narrowband mid-IR Laser Source for Molecular Spectroscopy “).
- Item 7 corresponds to a poster presentation during “The 20th International Conference on High Resolution Molecular Spectroscopy” (Prague, Czech Republic, 2-6 September 2008).
- Item 8 is a joint publication by HHUD, ORC, and TRT: Sergey Vasilyev, Stephan Schiller, Alexander Nevsky, Arnaud Grisard, David Faye, Eric Lallier, Z. Zhang, A. J. Boyland, J. K. Sahu, M. Ibsen, and W. A. Clarkson, “Broadly tunable single-frequency cw mid-infrared source with milliwatt-level output based on difference-frequency generation in orientation-patterned GaAs”, Opt. Lett., Vol. 33, Issue 13, pp. 1413-1415.

- Item 9 is a publication by ORC submitted to Optics Letters: Z. Zhang, D. Shen, A. J. Boyland, J. K. Sahu, M. Ibsen and W. A. Clarkson, "High power Tm-doped fiber distributed-feedback-laser at 1943 nm".
- Item 10 is a joint TRT/UVA communication to be presented by UVA: " Cathodoluminescence Study of orientation patterned OP-GaAs crystals for mid IR laser sources ", H. Angulo, M. Avella, J. Jiménez, D. Faye, A. Grisard, E. Lallier, B. Gerard, 17th European Workshop on Heterostructure Technology HeTech'08, Venice, Italy, 2-5/11/08.
- Item 11 is a joint TRT/UVA communication to be presented by TRT: " Growth and characterization of orientation-patterned gallium arsenide with low optical losses for quasi-phase matched nonlinear frequency conversion in the mid-infrared ", A. Grisard, D. Faye, E. Lallier, B. Gerard, M. Avella, J. Jimenez, Int. Conf. on the Physics of Semiconductors ICPS 2008, Session 13A: Materials and Growth, 27/07-01/08/08, Rio de Janeiro, Brazil.

Apart from this wider dissemination through standard scientific channels and the update of the project website http://www.neo.no/village/ (Google and Yahoo searches now respectively shows the Village website as fourth an seventh hit when typing "village infrared"), the second year of the project also enabled the extension of WP5 activities to other communication strategies. The key actions in this domain include :

- Registration of the project to the OPERA2015 website.
- Publication of a summary of the Village project, with a link to the project website, on the main ORC website http://www.orc.soton.ac.uk/319.html
- Submission of an exhibition proposal for the "ICT 2008 Conference" (Lyon, France, 25-27 November 2008). The VILLAGE exhibition proposal has been accepted on 16/07/2008 and is expected to provide an opportunity to advertise the project outputs to a very wide audience.

Finally, the participants dedicated more effort to search for related projects targeting health, food or security-related applications:

- In the health arena, breath analysis represents the most promising field for gas detection devices.
- While food applications are obvious candidates for spectrometric methods, there is a strong competition from other techniques both for cost and technical reasons.
- Trace gas analysis targeting hydrocarbons, greenhouse gas and pollutants is the field that gathers the largest number of research projects relying on infrared spectroscopy.

A number of ongoing projects will thus be followed with interest during next year and the VILLAGE consortium will seek opportunities to disseminate the project results correspondingly.