

WP5 PERIODIC REPORT

Grant Agreement number: 250072

Project acronym: ISENSE

Project title: Integrated Quantum Sensors

Funding Scheme: STREP (ICT-FET-Open)

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Periodic report: 1st ☐ 2nd ☐ 3rd ☒ 4th ☐

Period covered: from 1. July 2012 to 30. June 2013

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¹ Usually the contact person of the coordinator as specified in Art. 8.1. of the grant agreement

² The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm ; logo of the 7th FP: http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos). The area of activity of the project should also be mentioned.

5. Project management

- **Management tasks and achievements;**

Management tools

Management of the consortium involves several mechanisms. Each participant is required to provide the respective work package leader with a quarterly status update on the tasks he has carried out. The quarterly status updates are composed into quarterly status update reports for each work package produced by the respective work package leader. They summarize the preceding three months' of research and in particular highlight if the work package is on course to deliver the deliverables and milestones as prescribed in the proposal. If not on course they discuss the reasons and what remedies are sought to improve the situation and what potential knock-on effects there will be on other work packages.

The project coordinator holds meetings with individual work package leaders as required to monitor progress and problems, and apply corrective actions where necessary. They are also utilised by the coordinator to identify points where work packages meet and there are consequent impacts on integration. The level of detail in individual meetings is much higher than achievable in an hour long meeting of the STEM committee. In addition some work packages involving several sites have individual meetings as required to keep the workflow going smoothly. Overall, there have been ~20 such meetings in the reporting period.

Most of the meetings are using electronic communication tools such as Skype, Webex and email extensively. Important documents from meetings are posted regularly on the project wiki.

Following the positive past experience with establishing workgroups to push specific tasks we have further expanded this tool in the management of iSense. The following workgroups have been active during the last project period to push critical tasks:

- Laser Workgroup continuing from the last reporting period to coordinate laser integration activities. This workgroup is close to achieving all its tasks and is going to be phased out in the coming months once all remaining laser systems have been delivered.
- Magnetic Shield workgroup to push the development of a suitable magnetic shield for the iSense apparatus.
- Marketing Task Group to push the film and other outreach activities (see WP4)
- Vacuum workgroup: this workgroup has achieved its goals with the successful implementation of the vacuum system in Birmingham and was phased out.
- Waveguide workgroup to streamline the integrated optics system development.

Research coordination visits between partners

Date	Visiting partner	Visited Partner	Number travelling
28.-29.1.2013	OEAW-IQOQI	LUH	1
30.1.2013	OEAW-IQOQI	UHH	1
3.-9.2.2013	Bham	LUH	2
25.-26.03.2013	SYRTE	Bham	1
29.04.-10.05.2013	SYRTE	LUH	1

In addition we had numerous visits with discussions relevant to iSense between UNott and BHAM within the Midlands Ultracold Atom Research Centre, between UHH, LUH and

FBH within the QUANTUS collaboration as well as between the different subgroups included under CNRS (in particular SYRTE and IOGS).

Co-operation with other projects/programmes

An essential component of the iSense collaboration is to build on the existing expertise and foster synergies between fragmented related programmes across Europe, in particular the FINAQS, LASUS, QUANTUS, SAI, ICE, SOC, QWEP, STE-QUEST, QTEA and Matterwave projects. We co-operate with these projects via the direct involvement of iSense partners. This ensures that iSense technology developments are gauged by the up-to-date needs of the community and will find rapid and sustained use.

The following table gives an overview of particular collaborative activities:

Collaborating project	Lead Agency	Type of Collaboration	Collaborative work during reporting period
QUANTUS	DLR	Knowledge exchange and joint developments	Joint developments on advanced optical telescopes for laser beam shaping. Joint testing of fibre splitter components.
LASUS	DLR	Knowledge exchange and joint developments	Joint laser microintegration strategy developments allowed to develop a new more advanced laser generation to be included in iSense
ICE	CNES	Knowledge exchange and joint developments	Knowledge exchange on magnetic shielding, joint investigation of vacuum strategies
STE-QUEST	ESA	Knowledge exch.	Meetings with mutual representation
QTEA (ITN)	EC	Knowledge exchange and training of students	Meetings with mutual representation and joint training of early stage researchers.
Matterwave	EC	Knowledge exchange	Knowledge exchange on next generation atom chips and guided matterwave interferometers.

In addition iSense is using the respective project meetings to realise informal in-person meetings for the discussion and synchronisation of iSense matters. Some of these are:

Date	Venue	Programme	iSense partners meeting
2.-3.07.2012	Darmstadt	QUANTUS	Bham, LUH, UHH, FBH
27.07.2013	SYRTE	ICAP	SYRTE, OEAW-IQOQI
9.-12.10.2012	Cologne	Q2C5	CNRS, LUH, FBH, UNIFI
24.-26.10.2012	Hamburg	QTEA	Bham, UHH, UNOTT
13.11.2012	Bonn	Quantus	LUH, UHH, FBH
14.-15.02.2013	Hannover	Quantus	LUH, UHH, FBH
18.-22.03.2013	Hannover	DPG Conference	Bham, LUH, UHH, OEAW-IQOQI
8.-12.04. 2013	Birmingham	YAO	Bham, CNRS, LUH, FBH, UHH, UNIFI
19.-25.05.2013	Elba	GWADW	CNRS, UNIFI
23.-24.05.2013	ESTEC	STE-QUEST	Bham, LUH, FBH, UNIFI, SYRTE
7.-8.06.2013	Heraklion	Matterwave	Bham, UNOTT

- ***Problems which have occurred and how they were solved or envisaged solutions;***

We realised during the last review meeting that the original work programme did not foresee sufficient time to plan for magnetic shielding of the probe chamber and for testing and packaging of the integrated optics system. We have implemented a magnetic shielding workgroup and a waveguide workgroup to specifically push these tasks.

The magnetic shield workgroup has since decided upon a baseline shield solution, a strategy for active compensation for initial optimization steps and will finalize the shield design once the first interferometry signals have been achieved.

The waveguide workgroup has made good progress on identifying a suitable company for optical packaging. During the project meeting in Florence it was decided that optical packaging will be outsourced at the appropriate time and that no more action is needed from the waveguide workgroup in this respect. In addition the waveguide workgroup identified and removed a current bottleneck in optical testing of waveguide samples by designing and installing a suitable test system in Nottingham (see Task 1.1). The waveguide workgroup also provided and implemented a detailed wafer processing plan in order to mitigate delays in the realisation of the integrated optical system (see Task 1.1). With these measures we anticipate that the integrated optical system can be realised during the project.

During the project meeting in Florence delays in the microintegrated laser production became apparent, which have increased since. These delays are caused by technical risks such as thermal problems and failing thermosensors. The Laser Workgroup has been very helpful to minimize the consequences of these risks, however there is still a significant delay in the delivery of the integrated laser systems. We have thus in addition implemented an intermediate solution based on commercial laser systems, which allow establishing and optimizing system operation until the laser systems become available. This minimizes the overall project delay and we anticipate to be able to achieve full sensor operation before the end of the project.

There is a delay in the delivery of the chip current driver and the DDS boards. We will use standard power supplies and have identified suitable commercial DDS systems to allow optimization of the system until the respective boards are delivered. The impact on the overall objectives of the project will be thus minimized.

- ***Changes in the consortium, if any;***

Florian Schreck the key representative from OEAW-IQOQI has accepted an offer from University of Amsterdam and will move autumn 2013. The respective changes will be discussed during the review meeting.

- ***List of project meetings, dates and venues;***

Date	Venue	Purpose	N attending
12.-14.9.2012	Brussels	iSense progress, management and review meeting	25
30.01.2013	Teleconference	iSense progress meeting	9
11.-12.04.2013	Florence	Project progress and management meeting	18
28.05.2013	Teleconference	Laser mounting strategies	4
18.06.2013	Teleconference	iSense film planning	5

- ***Project planning and status;***

The project is meeting its scientific goals and despite some delay is anticipated to hit all the Milestones. The next year will see a strong focus on finalising and optimizing the iSense gravity sensor as well as a demonstration of the integrated optics system as important ingredient to the iSense technology platform. The respective work will mainly be done at Bham and UNOTT, both of which have significant remaining resources to address the associated work. This work will be supported and extended by the entire consortium in terms of expertise in subsystems and developments reaching into the future beyond iSense. Just before the review meeting we will discuss how to take the results of iSense forth in research and initiate workgroups to form consortia to prepare respective proposals. The ICT2013 meeting in Vilnius will provide a platform to demonstrate iSense to an interdisciplinary scientific community and make further contacts for these consortia. In Spring 2014 a project meeting at TOPTICA is planned with a focus on commercial outlook and dissemination.

- ***Impact of possible deviations from the planned milestones and deliverables, if any;***
We anticipate the delays in achieving the iSense milestones and deliverables to cause only minor impact on the overall project vision.

- ***Any changes to the legal status of any of the beneficiaries, in particular non-profit public bodies, secondary and higher education establishments, research organisations and SMEs;***

We can confirm that there have been no legal changes to the status of any of the beneficiaries.

- ***Development of the Project website, if applicable;***

The project has two web interfaces: an internal wiki and a globally accessible website. The wiki is being used extensively to support management activities. Project meeting minutes, documents on integration, slides from presentations and many other documents are stored on the wiki. The global website summarizes the project, introduces its members and disseminates new results. It is planned to expand this website during the next year.

- ***Use of foreground and dissemination activities during this period (if applicable).***

Publications

1. S. Pelisson, R. Messina, M.-C. Angonin, and P. Wolf, Dynamical aspects of atom interferometry in an optical lattice in proximity to a surface, *Phys. Rev. A* **86**, 013614 (2012).
2. T. Bourdel, “Phase diagrams of two-dimensional and three-dimensional disordered Bose gases in the local density approximation”, *Phys. Rev. A* **86**, 063626 (2012).
3. S. Stellmer, B. Pasquiou, R. Grimm, and F. Schreck, Creation of ultracold Sr₂ molecules in the electronic ground state: *Phys. Rev. Lett.* **109**, 115302 (2012), arXiv:1205.4505.
4. F. Sorrentino, A. Bertoldi, Q. Bodart, L. Cacciapuoti, M. de Angelis, Y.-H. Lien, M. Prevedelli, G. Rosi, and G. M. Tino, Simultaneous measurement of gravity acceleration and gravity gradient with an atom interferometer, *Appl. Phys. Lett.* **101**, 114106 (2012)
5. M. G. Tarallo, A. Alberti, N. Poli, M. L. Chiofalo, F.-Y. Wang, and G. M. Tino, Delocalization-enhanced Bloch oscillations and driven resonant tunneling in optical lattices for precision force measurements, *Phys. Rev. A* **86**, 033615 (2012).
6. B. Olmos, D. Yu, Y. Singh, F. Schreck, K. Bongs, and I. Lesanovsky, Long-Range Interacting Many-Body Systems with Alkaline-Earth-Metal Atoms: *Phys. Rev. Lett.* **110**, 143602 (2013), arXiv:1211.4537.

7. M. G. Tarallo, N. Poli, F.-W. Wang and G. M. Tino, Coherent control of quantum transport: Modulation-enhanced phase detection and band spectroscopy, *Eur. Phys. J.* **217**, 207 (2013)
8. S. Stellmer, R. Grimm, and F. Schreck, Production of quantum-degenerate strontium gases: *Phys. Rev. A* **87**, 013611 (2013), arXiv:1212.2539
9. S. Stellmer, B. Pasquiou, R. Grimm, and F. Schreck, Laser cooling to quantum degeneracy: *Phys. Rev. Lett.* **110**, 263003 (2013), arXiv:1301.4776. In the media: physicsworld
10. T. Vanderbruggen, R. Kohlhaas, A. Bertoldi, S. Bernon, A. Aspect, A. Landragin, and P. Bouyer, “Feedback Control of Trapped Coherent Atomic Ensembles”, *Phys. Rev. Lett.* **110**, 210503 (2013).
11. B. Pelle, A. Hilico, G. Tackmann, Q. Beaufils, F. Pereira Dos Santos, "State-labelling Wannier-Stark atomic interferometers", *Phys. Rev. A* **87**, 023601 (2013).

Conference/Workshop talks

1. F. Schreck, Strontium quantum gases: Fermions with SU(N) spin symmetries and more, Quark Gluon Plasma meets Cold Atoms - Episode III, 25-31 August 2012, Hirschegg, Austria.
2. Sorrentino, Gravity measurements with atom interferometry, Q2C5 conference, Cologne, 9-12 October 2012.
3. S. Stellmer/ B. Pasquiou, New tricks and old ideas: News from the Innsbruck Strontium Experiment, 5th Group-II-meeting, Tokyo, Japan, 11.October 2012.
4. F. Schreck, An outlook on ultracold strontium: laser cooling to quantum degeneracy, molecules, and many-body physics, Cold Atom Outlook 2012 - A European Endeavour, Aarhus, Danmark, 2. November 2012.
5. Protecting ensemble atomic coherence with weak measurements and feedback, Graduate College course in cold atoms and metrology, University of Hannover, Germany, 13 December 2012.
6. S. Stellmer, Laser cooling to quantum degeneracy, SFB meeting, Vienna, 13 December 2012.
7. Cold atoms, weak measurements and feedback for timekeeping, Lectio Magistralis at the opening of the Academic year, PhD School, University of Trento, Italy, 27 February 2013.
8. F. Schreck, A new dog for new tricks: Strontium for laser cooling to BEC, molecules, and many-body physics, FINES 2013, 20 February 2013.
9. K. Bongs, “Mapping the Underground”, Global Engagements Workshop, Nottingham, 6 March 2013.
10. S. Stellmer, Laser cooling to quantum degeneracy, Workshop Continuous Sources of Quantum Matter, Freudenstadt (Deutschland), 13 March 2013.
11. F. Schreck, Towards RbSr ground-state molecules: Rb / Sr double BEC & STIRAP to Sr₂ molecules, KITP Conference: New Science with Ultracold Molecules, 15 March 2013.
12. A. Bayerle, Double Bose-Einstein condensate of rubidium and strontium, DPG Frühjahrstagung, Hannover, 20 March 2013.
13. S. Stellmer, Laser cooling to quantum degeneracy, DPG Frühjahrstagung, Hannover, 22 March 2013.
14. F. Schreck, Repulsive polarons in a strongly interacting Fermi mixture, Newspin 3, Mainz, 3 April 2013.
15. T. Mazzoni, Gravity measurements with ultracold strontium atoms in an optical lattice, YAO 2013, Birmingham, 8-12 April 2013.
16. F. Sorrentino, The MAGIA experiment: current status and future prospects, GWADN 2013, Elba, 19-25. May 2013
17. B. Pasquiou, Double BEC of Rb and Sr: the power of sympathetic narrow-line cooling, DAMOP 2013, 6 June 2013.
18. F. Schreck, Laser cooling to quantum degeneracy, DAMOP 2013, 7 June 2013.

19. K. Bongs, "Quantum Sensors for Gravity and Time", JCQ Launch Workshop, Newcastle, 26 June 2013.

Conference/Workshop posters

1. F. Pereira dos Santos, B. Pelle, A. Hilico, Q. Beaufils, G. Tackmann, S. Pélisson, R. Messina, M.-C. Angonin, P. Wolf, "A trapped atom interferometer for short range forces measurements", ICAP 2012, The 23rd International Conference on Atomic Physics, Palaiseau (France), 23-27 July 2012.
2. S. Stellmer, Laser cooling to quantum degeneracy, 5th Group-II-meeting, Tokyo, Japan, 11 October 2012.
3. B. Pasquiou, Production of ultracold Sr₂ molecules in the electronic ground state, 5th Group-II-meeting, Tokyo, Japan, 11 October 2012.
4. K. Bongs, Miniaturization of Technology for Atom Interferometric Sensors, ITF Energy Oil and Gas Event, Aberdeen, 1. November 2012.
5. J. Malcolm, "iSense", IOP Quantum Technologies Meeting, IOP, London, 17 December 2012.
6. J. Malcolm, "iSense", DSTL Town Meeting: Precision Timing (and Navigation) technology, ISIC Harwell, 7 March 2013.
7. S. Tazanova, Towards the creation of ground-state RbSr molecules, DPG Frühjahrstagung, Hannover, 21 March 2013.
8. J. Malcolm, "iSense", Young Atoms Opticians conference 2013, Birmingham, 10 April 2013.
9. A. Hilico, B. Pelle, M.-K. Zhou, Q. Beaufils, G. Tackmann, S. Pélisson, M.-C. Angonin, P. Wolf and F. Pereira Dos Santos, "A trapped atom interferometer for the measurement of short range forces", ICOLS, 9-14 June 2013, Berkeley (USA)
10. B. Pelle, A. Hilico, M.-K. Zhou, Q. Beaufils, G. Tackmann, and F. Pereira dos Santos, "A trapped atom interferometer for the measurement of short range forces", ECAMP11, 24-18 June 2013, Aarhus (Denmark)