

Report on QTSpace WG3 meeting @ Arcachon, 5th July 2017, 3pm – 6pm

Goal of meeting: to work towards the deliverables of WG3 and to define the next proof of principle test for space missions with three different physical platforms (cold atoms [clocks and interferometers], quantum communication [photons], large particle matterwave interferometry and optomechanics). The first two milestones of WG3 are to *define the important experiments* to be done in space [with input from WG1 and WG2] and to *assess the technology readiness levels [TRLs]* for each platform.

Organizers: Philippe Bouyer, Hendrik Ulbricht

Participants: Peter Barker (UCL), Christopher Dawson (Swansea), Diaz Francisco (ETS), Rainer Kaltenbaek (Vienna), Jan Kohlrus (Vienna), Bruno Leone (ESA), Christoph Marquardt (Erlangen), Mauro Paternostro (Belfast), Erling Riis (Strathclyde), Guglielmo Tino (Firenze), George Winstone (Southampton).

We had several presentations to kick-off discussions and to start to define outputs for the defined milestones of WG3.

Presentation/discussion 1 - ESA: Bruno Leone updated on the structure of ESA [directorates] and what they fund and what they are interested in with respect to QT, Beside fundamental science mission for QT also exploration of ideas for Earth observation and Planetary exploration, technology development was recommended. ESA's budget is a large as never before, but it is unlikely to be used to significantly enhance the ESA funding for fundamental science. LISA has been approved as the L mission on fundamental science a couple of weeks ago, so any new fundamental science mission has be envisaged for after LISA and has to show significance and relevance. Leone announced the 2nd ESA QT conference at ESTEC, The Netherlands [14-15 November 2015], which will be organized together with QTSpace leaders. Leone pointed out again that it is important to work with the national delegates for almost any adventure related to space.

Presentation/discussion 2 - Cold atoms: Philippe Bouyer (Bordeaux) reported on cold atom [clocks and interferometers] efforts towards a big space mission which is going on for at least a decade. A lot of impressive technology has been build on very high technology readiness levels (TRL) by academia and industry, while ESA does not share this opinion and points out that the TLR depends on the specific conditions where the equipment is tests. Such conditions are different for space than in some of the tests. A discussion about this TRL definition is going on.

Many micro-gravity tests have been performed with cold atoms [drop towers, parabola flight, sounding rockets] and new are planned [Einstein elevators, etc.]. Commercial atom interferometers and atomic clocks are now available from different companies in the US, France, Germany and the UK. Commercial interest helps for the fostering of space programs. Many small project with cold atoms to test components in space and for smaller missions are ongoing, while developments towards a big fundamental science project with ESA proofs to be a tough process. The cold atoms community is considering, and indeed have been taken actions to explore possibilities for space missions without ESA, with industry and non-European space agencies.

Guglielmo Tino (Florence) reported on the experience with the cold atom submission "SAGE" for the 'ESA call for new science ideas'. SAGE is to use two or more cold atom experiments far

apart from each other and optically linked to detect gravitational waves. The proposal was based on published proposals and demonstrated technology, but not approved by ESA during a meeting at Trento in May 2017. ESA's assessment is that the technology is immature and the competition with LISA is not appreciated. Tino disputed the claim. Tino further explained that a manifold of fundamental science ideas can be tested with cold atom platforms [Einstein's equivalence principle, Dark Matter, etc.], while ESA commented of not being interested in such a 'Christmas tree' approach. ESA concluded to have a review of cold atoms for space, but details have to be defined.

Recommendation: QTSpace should evaluate if it is suitable to provide the platform to moderate the discussion between ESA and the cold atom community.

Presentation/discussion 3 - Quantum Communications (QC): Christoph Marquardt (MPL Erlangen) reported on exciting developments in quantum communications in space, where the expected need for quantum secure communication and the demonstration of space based quantum communication protocols by the recent Chinese satellite triggered a lot of interest from industry and governmental organizations. Different strategies for satellite to satellite and ground to satellite communication were explained and technological challenges described. QC in space is promising in many respects and could be implemented in many different ways and scales [different sized satellites]. The pull by industry is putting a rapid dynamics in the QC Space development in the international scale. QC space technology can build on existing mature heritage from classical communication in space.

Presentation/discussion 4 - Large-mass Matterwave Interferometry and Optomechanics: Rainer Kaltenbaek (Vienna, PI of MAQRO) gave an update on progress with the space mission MAQRO to perform a direct test of the quantum superposition principle in space. MAQRO had been [amongst other proposals for large mass quantum experiments in space] for the New science Ideas call at ESA and has been positively evaluated during the meeting in Trento. ESA showed general interest in a fundamental science mission on testing quantum mechanics in the post-LISA era. MAQRO has been invited to proceed with a maturation process and to define precisely the scientific question to be address by MAQRO as a first step on a trajectory towards a successful M class mission application. ESA further recommended to structure and extend the scientific community in support of MAQRO. This planned to be happening in the coming months and if successful would be invited for the CDF technical evaluation at ESA.

Comment by Mauro Paternostro [Queen's Belfast, Vice-Chair of QTSpace]: Paternostro reported on a community formation process underway to link QTSpace, relevant parts of the upcoming EU QTFlagship and ESA for QT in space. A structure of the action, coordinated by QTSpace leads together with the QTFlagship leader, has been proposed and is in the process of formation. A number of colleagues have been named to gather information in form of a document to be handed over to ESA director general at the ESA QTSpace conference in November 2017. That document is supposed to lay out the general interaction and potential for QT in space.

The meeting was concluded as a nice first steps towards the achievement of milestones of QTSpace's WG3. One aim for the coming year is to grow further the community of WG3.

06/07/2017 Hendrik Ulbricht