



Analysis on Optical Astronomy and Quantum Cryptography Applications

Presentation of the Draft Report

Survey of existing applications Draft at PM2

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Content of the WP 2120

This ppt presentation is excerpted from a large **Master Document** which discusses **the user communities and their needs**, with regard to time measurement and time distribution, for Astronomy and for Quantum Communications. Novel insights that have recently emerged are also presented.

The Master Document is divided in **two Chapters**:

- 1 - Astronomy**
- 2 - Quantum Cryptography**

with appropriate bibliographical References and web site listing, for each of them.

Appendixes contain detailed material useful for this WP 2120 and the subsequent one WP 4600.

1 – ASTRONOMY

We first consider two scenarios of existing applications:

1. single telescope operations
2. dual (or multiple) telescope in Michelson-type (phase) interferometric configuration

identifying their requirements.

Then, future applications (Quantum Astronomy, Hanbury Brown Intensity Interferometry) and their requirements will be expounded.

Identification of the Users Community - 1



Although the title of our WP is ‘optical telescopes’, we have found necessary to enlarge our survey to **ALL electromagnetic radiation (*light, photons*) telescopes on the ground and in space**, from Gamma Rays through UV, optical and IR, to Radio Waves.

Furthermore, we have considered other astronomical users who ***do not detect electromagnetic radiation***, but neutrinos and gravitational waves (e.g. ESA LISA). We could not perform a deep survey of their needs, however we mentioned them in our Master Document because **their requirements are no lesser than e.m. Astronomy**, and **synchronization is needed** on scientific and operational motivations.

Identification of Requirements - 2

Scientific examples:

- photometric variability** (photon flux vs. time) probes the **geometry** of the emitting region and the **emission mechanisms**,
- the time delay** between the occurrence of a given event in **different locations** determines the **position** of this event on the celestial sphere,
- the time delay of a burst on the two images** of a gravitational lens probes the dark matter content and the metric of the Universe
- the different arrival time of a neutrino and electromagnetic burst** could give the mass of the neutrino.
- Quantum correlation between the arrival time of photons**

Summary of Astronomical requirements

In extreme synthesis, for all branches of Astronomy, two different times must be considered:

- An **external** UTC (and correction to TAI) available to Earth based observers and to satellites throughout the solar system, in order to refer events to a common agreed time scale, with a precision of the order of 50-100 nanoseconds. Interruptions and post-processing of the time reference are **not** allowed.
- For particular applications, an **internal** clock providing a time stamp accurate to the 10-100 picosecond level for the duration of the experiment. (Stab. $1 \text{ e-}12$ at 1 sec) Post-processing would probably **be necessary**.
- For multiple telescope operation, individual clocks synchronized at the 10-100 picosecond level for the duration of the experiment (say 6 hours). Post-processing **is** allowed.

2 – Quantum Communication

The scenario that we consider in our WP 2120 for Quantum Key Distribution (QKD) is as follows:

- 1. QKD to/from fixed point to point communication.**
- 2. QKD to/from mobile (ground and/or space) terminals.**

Their different requirements have been identified.

Requirements-1

For QKD schemes, the strictest requirements is certainly the synchronization of the transmitter and the receiver.

It means that it is essential to know that the measure made at a certain instant t_1 is the measurement of the qubit sent at the instant t_0 .

Essential for:

noise rejection, exploitation of detectors capabilities and improvement of the key rate.

Relative Synchronization $< 1ns$

It is possible to use an hybrid-setup, where the Galileo receiver assures the authenticated and initial synchronization between the TX and RX, and then the ultra-precise alignment can be done with internal communication reference (dedicated optical pulse)

Requirements-2

The time accuracy may be used for key time-stamping and eventually authentication.

$$\text{Time accuracy} < 1\mu\text{s}$$

In the case of the synchronization of the transmitter and the receiver:

$$\text{Time stability} = 10^{-12} (\tau = 1\text{s})$$

Market analysis on Quantum Astronomy and QKD

...only an abstract on QKD:

European Commission Research Project (6° FP)



...security is the big deal in 7° FP

Performed Activity

Including both technical and programmatic aspects

- compiled document Harrison Project - Market Analysis Input
- updated Master Document: Optical Astronomy and Quantum Cryptography: Survey of existing applications to be distributed to PM2
- updated Survey Existing Application Astro Document HAR-UNPD-RP-R-001, and QKD HAR-UNPD-RP-R-002
- updated User Required Document Astro HAR-UNPD-RP-R-003, and QKD HAR-UNPD-RP-R-004
- *performed an in-depth technical survey of available equipments for time acquisition (in conjunction with University of Ljubljana and SEPA) to satisfy astronomical and quantum cryptography needs*
- *written a request to GSA for integration of funds and extension of activities (in conjunction with University of Ljubljana and SEPA)*
- started laboratory work in preparation of demonstrator units, in Padova, Asiago and Ljubljana; quantum detector received in Ljubljana, now under test; provisional timing unit (Rubidium oscillator) ordered for UPd.
- opened the UPd Web site for Harrison-connected activities <http://www.astro.unipd.it/quantumastronomy/> as contribution to WP 5200