**Introduction**

- Currently, microwave time transfer systems between ground and space reach a level of precision of the order of the nanosecond (about 1 to 30 ns achieved with the GPS). An integration on ~30 days would be necessary to reach the 10^{-17} level. That cannot support the performance requirements and goals of the future optical atomic clock in space missions (such as ESA-SOC) which aim at 10^{-17} level or better.
- Precise laser time and frequency-transfer from the ground to an orbiting satellite would make it possible to improve upon the current state of the art in timing by roughly a factor of 1000 to the 1 ps level.
- This would also enhance performance of existing systems and provide unique capabilities in navigation, precise timing, earth sciences, geodesy and the same approach could provide a platform for testing fundamental physics in space.

**Goals**

- Perform time and/or frequency transfer as precisely and accurately as possible
- Use of free space and fiber laser links
- Time measurements via precise phase measurements:
  - direct detection (optical pulses)
  - coherent detection (optical local oscillator)
- Laser source frequency stabilized: in the shorter (Fabry-Pérot cavity) and in the longer (Rb vapor) timescales
- Projected performance:
  - relative instability ~ 10^{-13} / √T, 1 s < t < 1000 s
  - repeatability, accuracy ~ 10^{-11}

**Experimental Setup**

**Key element:** Er-doped fiber mode-locked laser

**Results**

- Frequency lock stability:
  - Repetition rate frequency \( f_{\text{rep}} = 250 \text{ MHz} \)
  - Offset frequency: \( f_{\text{offset}} = 20 \text{ MHz} \)
- Optical frequency measurement:
  - Comb and CW laser beatnote:
    - \( V_{\text{comb}} = f_{\text{beatnote}} = n \times f_{\text{rep}} - f_{s} \)
    - Free running laser frequency measurement:
- Fiber-link noise:
  - \( S_{\text{link}}(f) = 1.7 \mu \text{V} / \text{VHz} \)

**Conclusions and Perspectives**

- Laser locking on atomic transition:
  - Comb and/or CW laser frequency doubling
  - New vacuum chamber designed and installed
  - Cavity tested
  - Laser diagnostic
- Laser locking on high finesse Fabry-Pérot cavity:
  - Amplitude and frequency modulation:

**Acknowledgements**

We would like to thank all the members of the group: Sarah Sheldon, Andrey Sushko, Chris Tang and Zoe Yan.

We are also indebted to Sasha Buchman, John Lipa, Shally Saraf and Alberto Stochino for fruitful discussions.

This work is supported by the NASA – Fundamental Physics program and the DARPA – Quantum Assisted Sensing and Readout (QUASAR) program.