Engineering a 2-Colour Compact Rubidium Optical Clock for Space

J. Scarabel[1], C. R. Locke[1], T-L. Nguyen[1], G. Harris[1], J. Gray[1], Y. Ooi[1], M. Burns[1], S. Scholten[2], N.B. Hébert[2], E. Ahern[2], C. Perrella[2], S. Ng[1,2], M. O'Connor[1,2], A. Luiten[1,2]

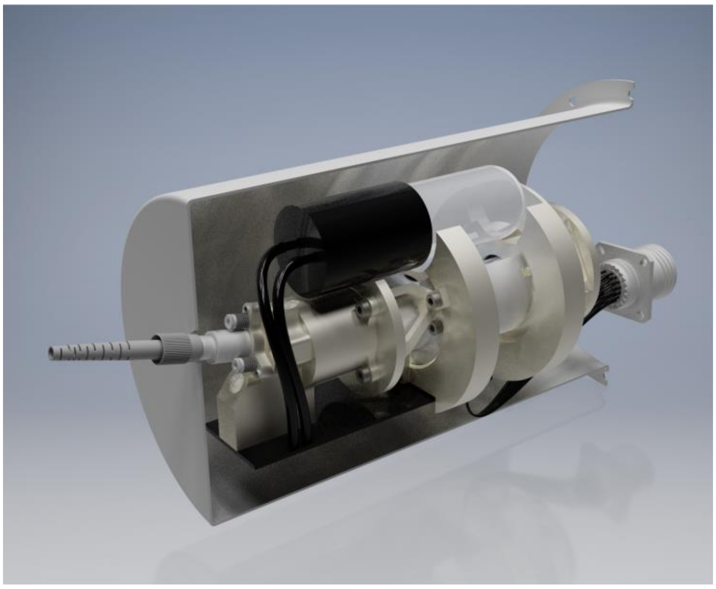
1. QuantX Labs Pty Ltd, Adelaide, SA, Australia
2. The University of Adelaide, Institute for Photonics and Advanced Sensing, Adelaide, SA, Australia

email: Jordan.scarabel@quantxlabs.com

Sovereign Global Navigation Satellite Systems (GNSS) [1,2] are highly desirable for risk mitigation for ensured position, navigation, and timing services, critical to many services of modern society such as power distribution networks, supply chains, and national security. This growing dependence on ensured timing [3] combined with the reduced cost of launching space services has led to an incentive to develop next-generation satellite-enabled technologies. The two-photon $5^2S_{1/2}$-$5^2D_{5/2}$ transition in rubidium offers a frequency reference with a high spectroscopic signal to noise and atomic linewidth suitable for probing without an ultra-stable external reference cavity, from which a low size, weight, and power (SWaP) clock can be developed [4] with potential order of magnitude improvement in performance over existing technology.

The $5^2S_{1/2}$-$5^2D_{5/2}$ transition can be excited using two lasers at 780 nm and 776 nm tuned near the intermediate $5^2P_{3/2}$ state, which allows for much less optical power compared to excitation using a single colour at 778 nm. The two-colour clock, however, requires a more complex control scheme and a lower relative intensity noise on the probing lasers to achieve similar short- and long-term stability. The lower optical power reduces the SWaP requirements by taking advantage of highly engineered telecom industry laser technology to derive the probe light at 780 nm and 776 nm with no post-laser optical amplification.

The pre-flight design presented in this work further develops the portable clock developed by the University of Adelaide for use in a space environment, having a target SWaP of 20 L, 20 kg and 100 W. Some of its considerations are the mitigation of orbit driven thermal fluctuations, improved power efficiency of control logic, and the compact packaging of an optical frequency comb [5].



Conceptual design of the "physics package" of the compact rubidium optical clock.

References

[1] T. N. Bandi, J. Kaintura, A. R. Saiyed, B. Ghosal, P. Jain, R. Sharma, P. Priya, K. Shukla, S. Mandal, N. Reddy, A. Soni, S. Somani, A. Patel, D. Attri, D. Mishra, T.V.S. Ram, K. Parikh, "Indian Rubidium Atomic Frequency Standard (iRAFS) Development for Satellite Navigation," 2019 URSI Asia-Pacific Radio Science Conference (AP-RASC), 1-1, (2019).

[2] John W. Betz, "Quasi-Zenith Satellite System," Engineering Satellite-Based Navigation and Timing: Global Navigation Satellite Systems, Signals, and Receivers, 266-281 (2016)

[3] P. Banerjee, "Timing in GNSS - its importance and challenges," 2015 International Conference on Microwave and Photonics (ICMAP), 1-2, (2015)

[4] C. Perrella, P. S. Light, J. D. Anstie, F. N. Baynes, R. T. White, & A. N. Luiten, "Dichroic two-photon rubidium frequency standard", Physical Review Applied, 12(5), 054063 (2019).

[5] L. C. Sinclair, J.-D. Deschênes, L. Sonderhouse, W. C. Swann, I. H. Khader, E. Baumann, N. R. Newbury, and I. Coddington, "A compact optically coherent fiber frequency comb", Review of Scientific Instruments. 86, 081301 (2015).