Development of a Compact Clock for Small Satellite Applications

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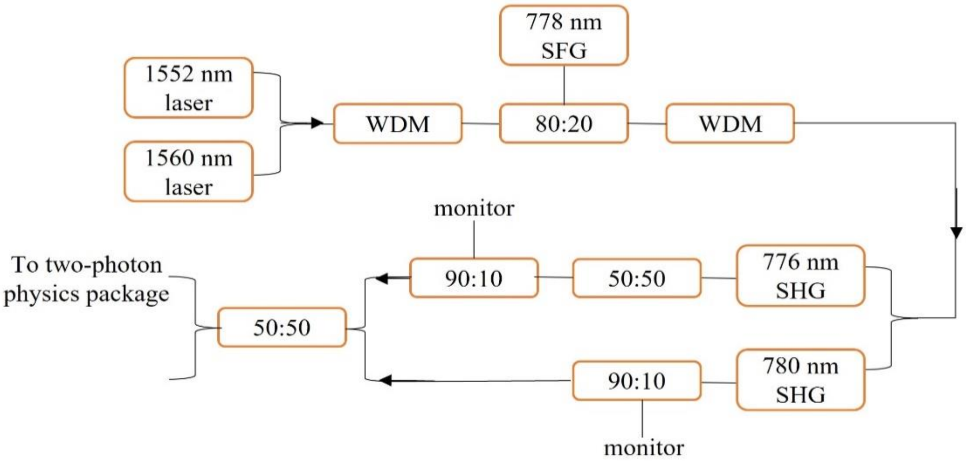

Figure 1 – Optical layout of the compact clock for small satellite applications. WDM: wavelength division multiplexer; SFG: sum frequency generation crystal; SHG: second harmonic generation crystal.

Atomic frequency standards have provided precise timing devices for global navigation satellite systems (GNSS) since the first activation of the global positioning system (GPS) in the early 1990's [1].]. Today, there are four GNSS; GPS (USA), GLONASS (Russia), BeiDou (China), and Galileo (Europe). These satellite systems are all in medium earth orbit (MEO) or geostationary orbit. Due to the distance GNSS signals must travel, they are subject to significant free space loss before they reach Earth, which is the main contributing factor to their vulnerability to jamming and spoofing [2]. Atomic clocks of lower size, weight, and power (SWaP) requirements may be able to mitigate this vulnerability by being placed in orbits closer to Earth, reducing free space loss, thus increasing GNSS signal strength at Earth.

In recent decades optical clocks based on a single colour two-photon transition between the $5S_{1/2}$ and $5D_{5/2}$ states in Rubidium vapour have been in development worldwide. We report on a two-colour implementation of this clock using 780nm and 776nm lasers to excite the transition – which allows for a stronger excitation rate, offsetting the effect of residual doppler broadening due to the two different wavelengths driving the transition resulting in a 25-fold increase in excitation [3]. Now, we present improvements to the size, weight, and power consumption (SWaP) of this two-photon Rubidium clock, toward a small satellite compatible frequency standard. Through careful choice of components, we have developed a prototype with a size of 20 L, weight of 10 kg, and power consumption of 98 W, paving the way for a low SWaP alternative for the next generation GNSS.

[1] T. P. Yunck, C. H. Liu, and R. Ware, *A History of GPS Sounding*, Terr. Atmos. Ocean. Sci. **11**, 1 (2000).

[2] F. Dovis, *GNSS Interference Threats and Countermeasures* (Artech House, 2015).

[3] C. Perrella, P. S. Light, J. D. Anstie, F. N. Baynes, R. T. White, and A. N. Luiten, *Dichroic Two-Photon Rubidium Frequency Standard*, Phys. Rev. Appl. **12**, 1 (2019).