National Aeronautics and Space Administration

FY25 Strategic University Research Partnership (SURP)

Optical local oscillator enabling all-optical timescale

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Objectives

Develop a transportable optical local oscillator (OLO) based on 21-cm crystalline silicon cavity to support

1. Silicon OLO $10^{-17}$and frequency drift 10^{-20} /s (10 mHz/s or 1 Hz /day).

2. All optical timescale, 100 times improvement over the current microwave

3. Frequency and timing reference for space mission, e.g. optical clock, VLBI…

Approach

General:

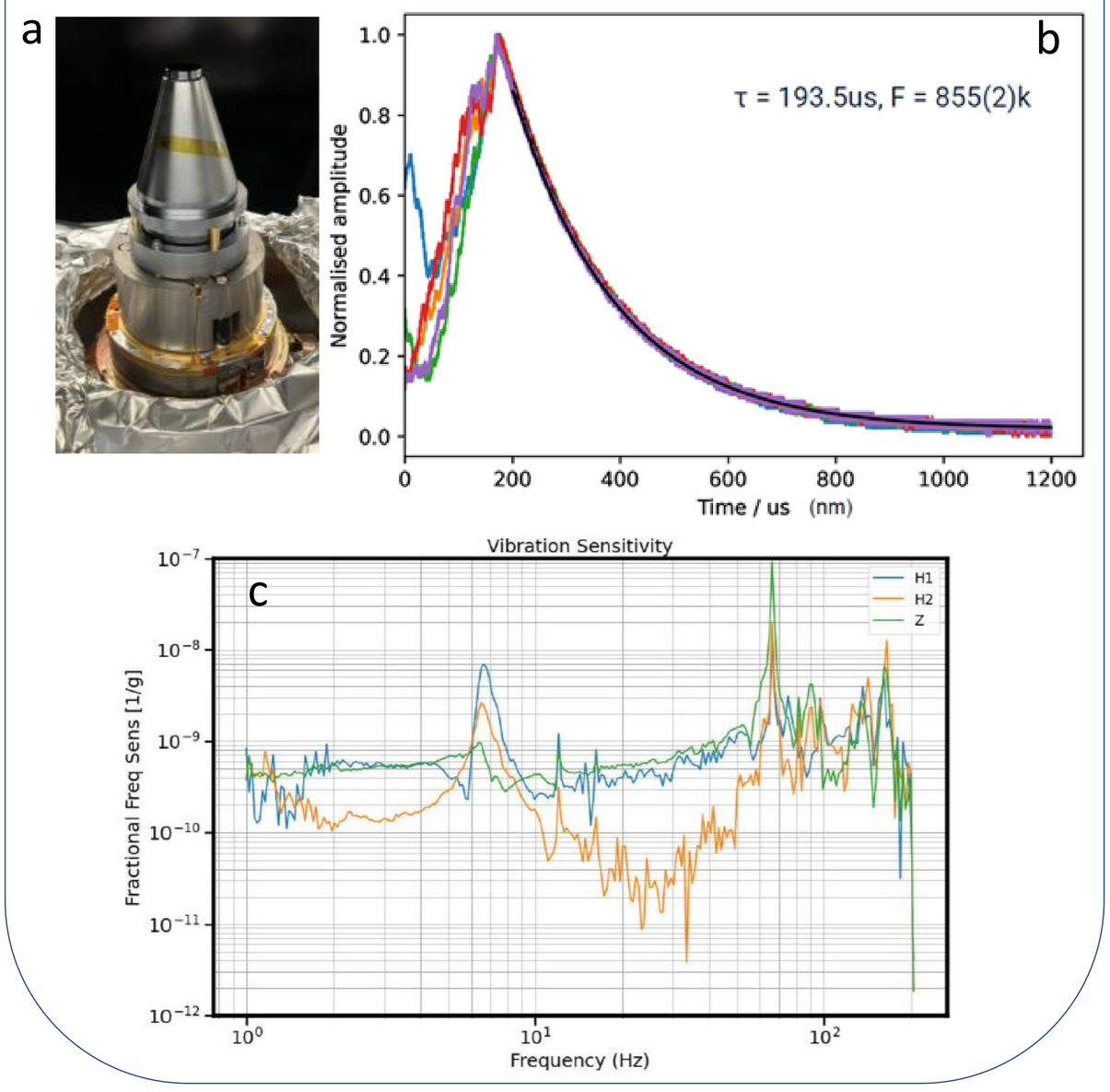
1. a continuous wave laser at 200 THz is frequency locked to the silicon cavity.
2. The temperature of the cavity is cooled down to 17 K by the pulse tube cryocooler. 3
3. For time keeping purpose, the OLO frequency is down-converted by the frequency comb for pulse/second signal generation.

Technical:

1. Insensitive to vibration. The cavity is vertically installed, and the optical axis is aligned with the <111> direction, a vibration sensitivity of $1x10^{-11}$/g
2. Thermal isolation. Multilayer thermal shield, temperature-induced noise is well below the thermal noise up to 1000 s averaging time
3. All-optical timescale. OLO frequency will be continuously tuned by the AOM to keep on the Sr clock transition

Results

1. The cavity is designed to be football shaped with tapered ends and 21 cm length. The cavity has been assembled and installed in the vacuum chamber (Figure a)
2. The cavity finesse is measured to be 0.855(2) million, reaching our target finesse value range (Figure b)
3. The vibration sensitivity is 10^{-10}/g level. Will continue to optimize(Figure c)



Significance/Benefits

1. The optical timescale will enable precise timing systems, e.g. 100 improvement in time error in DSN
2. Meet stability requirement in space VLBI, listed in 2022 Astrophysics Strategic Technology Gaps

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