



NASA SBIR 2019 Phase I Solicitation

S1.10 Atomic Interferometry

Lead Center: GSFC

Participating Center(s): GSFC, JPL

Technology Area: TA8 Science Instruments, Observatories & Sensor Systems

Recent developments of laser control and manipulation of atoms have led to new types of precision inertial force and gravity sensors based on atom interferometry. Atom interferometers exploit the quantum mechanical wave nature of atomic particles and quantum gases for sensitive interferometric measurements. Ground-based laboratory experiments and instruments have already demonstrated beyond the state-of-the-art performances of accelerometer, gyroscope, and gravity measurements. The microgravity environment in space provides opportunities for further drastic improvements in sensitivity and precision. Such inertial sensors will have great potential to provide new capabilities for NASA Earth and planetary gravity measurements, for spacecraft inertial navigation and guidance, and for gravitational wave detection and test of properties of gravity in space.

Currently the most mature development of atom interferometers as measurement instruments are those based on light pulsed atom interferometers with freefall cold atoms. There remain a number of technical challenges to infuse this technology in space applications. Some of the identified key challenges are (but not limited to):

- Compact high flux ultra-cold atom sources for free space atom interferometers (Example: $>1e+06$ total useful free-space atoms, <1 nK, Rb, K, Cs, Yb, Sr, and Hg. Performance and species can be defined by offerors). Other related innovative methods and components for cold atom sources are of great interest, such as a highly compact and regulatable atomic vapor cell.
- Ultra-high vacuum technologies that allow completely sealed, non-magnetic enclosures with high quality optical access and the base pressure maintained $<1e-09$ torr. Consideration should be given to the inclusion of cold atom sources of interest.
- Beyond the state-of-the-art photonic components at wavelengths for atomic species of interest, particularly at NIR and visible: efficient acousto-optic modulators (low RF power ~ 200 mW, low thermal distortion, $\sim 80\%$ or greater diffraction efficiency); efficient electro-optic modulators (low bias drift, residual AM, and return loss, fiber-coupled preferred), miniature optical isolators (~ 30 dB isolation or greater, ~ -2 dB loss or less), robust high-speed high-extinction shutters (switching time < 1 ms, extinction > 60 dB are highly desired).
- Flight qualifiable lasers or laser systems of narrow linewidth, high tunability, and/or higher power for clock and cooling transitions of atomic species of interest. Cooling and trapping lasers: 10 kHz linewidth and ~ 1 W or greater total optical power. Compact clock lasers: $5e-15$ Hz/v?? near 1 s (wavelengths for Yb+, Yb, Sr clock transitions are of special interest).
- Analysis and simulation tool of a cold atom system in trapped and freefall states relevant to atom interferometer and clock measurements in space.

All proposed system performances can be defined by offerors with sufficient justification. Subsystem technology

development proposals should clearly state the relevance, define requirements, relevant atomic species and working laser wavelengths, and indicate its path to a space-borne instrument.

Currently, no technology exists that can compete with the potential sensitivity, (potential) compactness, and robustness of Atom Optical-based gravity and time measurement devices. Earth science, planetary science, and astrophysics all benefit from unprecedented improvements in gravity and time measurement. Specific roadmap items supporting science instrumentation include, but are not limited to:

- TA-7.1.1: Destination Reconnaissance, Prospecting, and Mapping (gravimetry)
- TA-8.1.2: Electronics (reliable control electronics for laser systems)
- TA-8.1.3: Optical Components (reliable laser systems)
- TA-8.1.4: Microwave, Millimeter, and Submillimeter-Waves (ultra-low noise microwave output when coupled w/ optical frequency comb)
- TA-8.1.5: Lasers (reliable laser system w/ long lifetime)

The desired deliverables are prototype hardware/software, documented evidence of delivered TRL (test report, data, etc.), summary analysis, and supporting documentation. The expected Technology Readiness Level (TRL) range at completion of the project is 3-5.

References:

- 2017 NASA Strategic Technology Investment Plan: <https://go.usa.gov/xU7sE>
- 2015 NASA Technology Roadmaps: <https://go.usa.gov/xU7sy>