NASA SBIR/STTR — Small Business Innovation Research / Small Business Technology Transfer

NASA SBIR 2014 Phase I Solicitation

S1.09 Atomic Interferometry

Lead Center: JPL

Participating Center(s): GSFC

Recent developments of laser control and manipulation of atoms have led to a new type 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. 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 (>$1x10^6$ total useful free-space atoms, <1 nK, Rb, K, Cs, Yb, Sr, and Hg are example candidates but others can be justified by the offeror).
- Ultra-high vacuum seal technologies that allow completely sealed, non-magnetic enclosures with high quality optical access (base pressure maintained <$1x10^{-9}$ 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 or less, low thermal distortion, ~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 of narrow linewidth and higher power for clock and cooling transitions of atomic species of interest. Clock lasers: 1 $Hz/s^{1/2}$ at 1 s, ~ 1W output power or greater; Cooling and trapping lasers: 10 kHz linewidth and ~ 1 W or greater.
- Analysis and simulation tool of cold atom system in trapped and freefall states relevant to atom interferometer and clock measurements in space.

The 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.

Recognizing the fact that the field of atom interferometry is an active research field and there are potential breakthrough approaches still being investigated in research laboratories, NASA is also interested in new ideas of atom interferometry that will lead to better and smaller inertial sensors for rotational sensors, accelerometers, and gravity measurement instruments and will benefit and enable future NASA space missions. Therefore, this subtopic call is also soliciting practical approaches to new sensor ideas that may have high risk but can have high payoffs. Some of the known examples are:

- Bose Einstein condensate based sensors.
- Sensors using large momentum transfer.
- Guided atom wave sensors.
- Non-classical atom interferometers.
- Any other cold atom-based sensor technology such as optical clocks.