Draper Advanced Position, Navigation, and Timing Research Interests

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Introduction

Draper has been active in the research and fielding of advanced positioning, navigation, and timing (APNT) for multiple decades. We have worked on, developed, and demonstrated APNT solutions that span celestial navigation to chip-scale atomic clock timing to underwater navigation modes. Draper's APNT portfolio stretches across many domains and accesses all technology readiness levels. We continue to seek cutting-edge ideas and technologies that drive the state of the art forward.

About Draper Laboratory (www.draper.com)

Draper is an independent, not-for-profit corporation, chartered to work on problems in the national interest. Draper is seeking collaborative research partners from universities to further the state of the art in key technologies of mutual interest. Research Whitepapers describing Draper's technology interests and Technical Points of Contact can be found on the Draper Scholars webpage (Draper Scholar Program | Draper). The Draper Scholars Program funds thesis-bearing MS and PhD students at partner universities as one of the effective ways to progress the technology. Other means of collaborative research (e.g. joint proposals, sabbaticals, etc.) are also encouraged. Please contact education@draper.com if you have further questions.

Research Interests

1. Celestial Navigation

The ability to measure celestial objects across different spectral regions, using advanced imaging processing techniques, utilizing ultrasensitive detection techniques, and/or leveraging adaptive optics can enable significant increases in observational capacity and ultimately better positional accuracies. We seek to foster a number of different modalities that can improve the imaging of celestial objects (including those in Earth orbit). Some questions that we are interested in are:

- How can non-centrosymmetric optics be used to improve compact telescope designs (particularly by removing obscurants)?
- Can size-, weight-, and power-constrained focal plane arrays be built that examine multiple spectral regions? Can multiple focal plane arrays be used in highly limited form factors to increase spectral ranges?
- Are there novel methods for sensing and correcting incoming light through highly degrading environments or rapidly changing conditions?
- How can field of view be maximized while limiting or eliminating aberrations (spherical, chromatic, etc.)? Are there techniques, methods, or processes for achieving very high fields of view?

2. Advanced MEMS Sensing

Details for this area will be provided soon.

3. Edge Sensing Methods

A key challenge for APNT is distinguishing critical data from meaningless data. Traditional sensors accept all data that surpasses their detectability limits, which means that they are always on (power hungry) and are constantly outputting data (which necessitates processing capabilities). The use of new methods, such as AI/ML, neuromorphic sensors, sparse sampling, and multi-hub/multi-node webs can help mitigate this data avalanche at the edge of the sensor/phenomena interface. We seek insights into the following questions:

- How can we use edge sensing/data fusion methods to reduce sensor power consumption and sensor failure rates?
- Can we use neuromorphic sensing methods to significantly evolve/change sensor functionality and operation without human intervention?
- For a given detection system, can we significantly improve processing capacity but still maintain overall detection capability by reducing irrelevant sensor outputs?

4. Clocks and Timing

Atomic and molecular systems provide a set of highly precise and accessible energy levels that can be used for precision timing. Some questions we are seeking insight into are:

- How can we reduce the size of chip-scale atomic clocks? Can we move to much higher frequencies (e.g., terahertz) for intra-atomic coupling?
- How can we rapidly and accurately synchronize multiple independent clocks that are spatially separated?
- Beyond the commonly used systems, what other atomic or molecular gases have the potential to achieve very high timing precision? Can the ancillary support structures also be miniaturized and packaged?

5. Quantum sensing

We seek advancements in atomic and molecular sensing of electric and magnetic field, such as:

- Use of Rydberg atoms to simultaneously sense both electric (RF) and magnetic fields. Can detectability be increased? Can the detection be shown to be vectorized?
- Atomic gravimetry for precision sensing of gravity in highly constrained (size, weight, and power) packages and/or unstable platforms (e.g., moving vehicles, airplanes, ships, etc.).
- Use of atomic or molecular gases for very high precision magnetic field detection (magnitude or vectorized).
- Low-dimensional materials for sensing acoustics (air or underwater) at very specific frequencies (narrowband) and very high detectabilities.
- Ionic, atomic, dopant, or vacancies in materials that can be used for magnetic field sensing, such as nitrogen vacancies in diamond, dopants or inclusions in optical fiber for Faraday rotation detection, or magnetic dopants in quantum dots.

6. Quantum materials

A new generation of materials has shown that when the material size becomes similar to or less than the size of relevant quantum wavefunctions, new capabilities and novel physics can be achieved. We seek a greater understanding of how room-temperature phenomena in these materials can be used in chip-scale packaging for very sensitive detection or manipulation of electric, magnetic, acoustic, optical, or quantum behaviors. Topics may include:

- Spontaneous self-assembly of materials to form a simple device or sensor.
- High-performance materials (e.g., graphene, topological insulators, phase-change materials, etc.) that can be used for sensors that manipulate light.

- Electrical control of light-matter interactions, such as rapid control over indices of refraction, high-speed manipulation of reflection/absorption/transmission, or coherent energy transfer to/from incoming light in a narrowband frequency region.
- Materials that can be used for novel acoustic sensors.

We would be targeting PhD students for the development of novel approaches; and MS students for the application of existing approaches to specific problems of interest to Draper.