A Compact, High-Flux Cold Atom Beam Source

High atom loading efficiency is important for compact and mobile devices where laser power and space are limited.

NASA's Jet Propulsion Laboratory, Pasadena, California

The performance of cold atom experiments relying on three-dimensional magneto-optical trap techniques can be greatly enhanced by employing a high-flux cold atom beam to obtain high atom loading rates while maintaining low background pressures in the UHV MOT (ultra-high vacuum magneto-optical trap) regions. Several techniques exist for generating slow beams of cold atoms. However, one of the technically simplest approaches is a two-dimensional (2D) MOT. Such an atom source typically employs at least two orthogonal trapping beams, plus an additional longitudinal "push" beam to yield maximum atomic flux.

A 2D atom source was created with angled trapping collimators that not only traps atoms in two orthogonal directions, but also provides a longitudinal pushing component that eliminates the need for an additional push beam. This development reduces the overall package size, which in turn, makes the 2D trap simpler, and requires less total optical power. The atom source is more compact than a previously published effort, and has greater than an order of magnitude improved loading performance.

An effective pushing field component was realized by tilting the 2D MOT collimators towards a separate three-dimensional (3D) MOT in ultra-high vacuum. This technique significantly improved 3D MOT loading rates to greater than 8×10^9 atoms/s using only 20 mW of total laser power for the source. When operating below saturation, a maximum efficiency of 6.2×10^{11} atoms/s/W was achieved.

One of the most significant improvements of the present 2D MOT over conventional elliptical-beam 2D MOT designs is the angle of the collimators with respect to the axis of the 2D MOT. Both the horizontal and vertical collimators have been optimized to include forward tilt. Associated retro-mirrors are mounted parallel to the axis of the 2D MOT, thus insuring that the reflected beams are also projected forward at the same angle as the incident beams, effectively resulting in a pushing component with a fraction of the overall laser field in each orthogonal direction. The increased push factor at larger collimator angles is offset by reduced lateral trapping efficiency. It is worth noting that the intrinsic symmetry of a retro-reflected beam setup is very robust and simple to use.

The forward-angled collimator method allows for high 2D atomic flux without the need for an additional push laser and associated optical and electronic hardware. This cold atom source maintains very high efficiencies while utilizing a simpler, more compact, and more robust package than previous atom sources. The compact design and efficiency of the current apparatus is suitable for cold atom applications in the laboratory, and especially in mobile devices, including cold atom instruments in space.

This work was done by James R. Kellogg, James M. Kohel, Robert J. Thompson, David C. Aveline, and Nan Yu of Caltech; and Dennis Schlippert of the Institut für Quantenoptik, Hannover, Germany for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-48322

Sample-Clock Phase-Control Feedback

The throughput of a pulse-position modulation with 16 slots can increase from 188 Mb/s to 1.5 Gb/s.

NASA's Jet Propulsion Laboratory, Pasadena, California

To demodulate a communication signal, a receiver must recover and synchronize to the symbol timing of a received waveform. In a system that utilizes digital sampling, the fidelity of synchronization is limited by the time between the symbol boundary and closest sample time location. To reduce this error, one typically uses a sample clock in excess of the symbol rate in order to provide multiple samples per symbol, thereby lowering the error limit to a fraction of a symbol time. For systems with a large modulation bandwidth, the required sample clock rate is prohibitive due to current technological barriers and processing complexity. With precise control of the phase of the sample clock, one can sample the received signal at times arbitrarily close to the symbol boundary, thus obviating the need, from a synchronization perspective, for multiple samples per symbol.

Sample-clock phase-control feedback was developed for use in the demodulation of an optical communication signal, where multi-GHz modulation bandwidths would require prohibitively large sample clock frequencies for rates in excess of the symbol rate. A custom mixed-signal (RF/digital) offset phase-locked loop circuit was developed to control the phase of the 6.4-GHz clock that samples the photon-counting detector output. The offset phase-locked loop is driven by a feedback mechanism that continuously corrects for variation in the symbol time due to motion between the transmitter and receiver as well as oscillator instability. This innovation will allow significant improvements in receiver throughput; for example, the throughput of a pulse-position modulation (PPM) with 16 slots can increase from 188 Mb/s to 1.5 Gb/s.

The novelty of this innovation is precise control of the sample-clock phase supports synchronization to the symbol timing of the received waveform without the use of a sample clock in excess of the symbol rate. This can reduce the required sample clock frequency for demodulation of a communication signal, and thereby reduce the processing complexity as well as permit demodulation of large bandwidth signals for which there was a technological barrier to a sample frequency in excess of the symbol rate.

Sample-clock phase-control feedback has direct applications in optical and radio frequency communication systems for satellite and deep space applications, as well as other applications in high-precision timing.

This work was done by Kevin J. Quirk, Jonathan W. Gin, Danh H. Nguyen, and Huy Nguyen of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). **NPO-47663**

360° Camera Head for Unmanned Sea Surface Vehicles

NASA's Jet Propulsion Laboratory, Pasadena, California

Autonomous navigation and control for unmanned sea surface vehicles requires a visual sensing system to provide a 360° view from the vehicle deck for situational awareness. Successful operation required a sensing system mechanically packaged to withstand weather, sea spray, and an environment of continual motion and mechanical shock. A low-cost, easily manufacturable, watertight, and mechanically robust sensing system was developed for autonomous navigation and intelligent control.

The 360° camera head consists of a set of six color cameras arranged in a circular pattern such that their overlapping fields of view give a full 360° view of the immediate surroundings. The cameras are enclosed in a watertight container along with support electronics and a power distribution system. Each camera views the world through a watertight porthole. To prevent overheating or condensation in extreme weather conditions, the watertight container is also equipped with an electrical cooling unit and a pair of internal fans for circulation.

Most JPL systems use cameras that are pointed at targets either through actuation or motion of the host vehicle. The 360° six-camera layout allows full situational awareness in all directions with no actuation required. Also novel is the watertight design, which encases all six cameras in a cylinder with six symmetrically placed windows. Each window employs a porthole-style design, in which the circular glass pane is sealed against an O-ring to prevent leaking. All cylinder access panels are similarly sealed with O-rings, and the electrical cooling unit, which sits half inside and half outside the camera head, is sealed with closed cell silicone foam.

This design proves the utility of 360° visual sensing to enhance situational awareness for Naval Unmanned Sea Surface Forces. The concept could be applied to future space missions to increase visual situational awareness without increasing actuation requirements.

This work was done by Julie A. Townsend, Eric A. Kulczycki, Reginald G. Willson, Terrance L. Huntsberger, Michael S. Garrett, Ashitey Trebi-Ollennu, and Charles F. Bergh of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Management Office–JPL. Refer to NPO-47717.

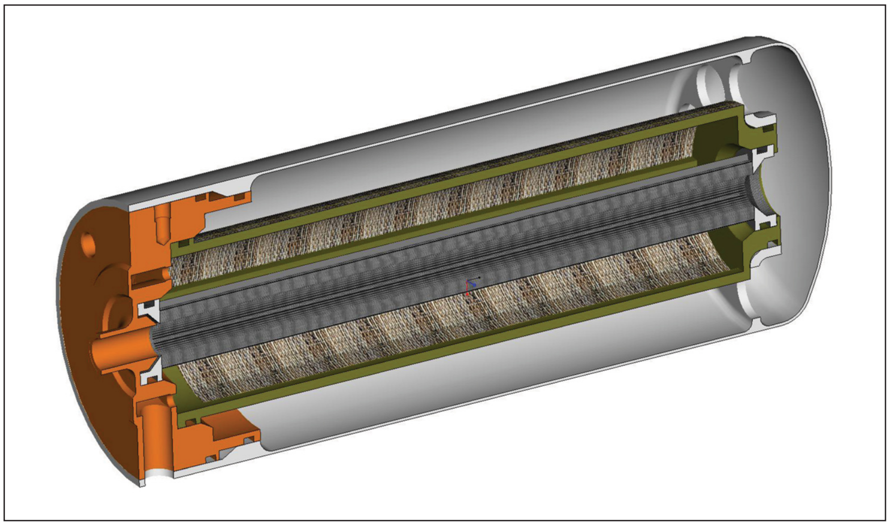
Microgravity Passive Phase Separator

There are no moving parts and there are no failure modes that involve fluid loss.

Lyndon B. Johnson Space Center, Houston, Texas

A new invention disclosure discusses a structure and process for separating gas from liquids in microgravity. The Microgravity Passive Phase Separator consists of two concentric, pleated, woven stainless-steel screens (25-μm nominal pore) with an axial inlet, and an annular outlet between both screens (see figure). Water enters at one end of the center screen at high velocity, eventually passing through the inner screen and out through the annular exit. As gas is introduced into the flow stream, the drag force exerted on the bubble pushes it downstream until flow stagnation or until it reaches an equilibrium point between the surface tension holding bubble to the screen and the drag force.

Gas bubbles of a given size will form a "front" that is moved further down the



Microgravity Passive Phase Separator