



## Atom Skimmers and Atom Lasers Utilizing Them

Atom skimmers act as conduits and low-pass velocity filters.

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Atom skimmers are devices that act as low-pass velocity filters for atoms in thermal atomic beams. An atom skimmer operating in conjunction with a suitable thermal atomic-beam source (e.g., an oven in which cesium is heated) can serve as a source of slow atoms for a magneto-optical trap or other apparatus in an atomic-physics experiment. Phenomena that are studied in such apparatuses include Bose-Einstein condensation of atomic gases, spectra of trapped atoms, and collisions of slowly moving atoms.

An atom skimmer (see figure) includes a curved, low-thermal-conduction tube that leads from the outlet of a thermal atomic-beam source to the inlet of a magneto-optical trap or other device in which the selected low-velocity atoms are to be used. Permanent rare-earth magnets are placed around the tube in a yoke of high-magnetic-permeability material to establish a quadrupole or octupole magnetic field leading from the source to the trap. The atoms are attracted to the locus of minimum magnetic-field intensity in the middle of the tube, and the gradient of the magnetic field provides centripetal force that guides the atoms around the curve along the axis of the tube. The threshold

velocity for guiding is dictated by the gradient of the magnetic field and the radius of curvature of the tube. Atoms moving at lesser velocities are successfully guided; faster atoms strike the tube wall and are lost from the beam.

In the example of the figure, the magnets are made of NdFeB, a material that provides the largest fields. The inner diameter of the tube is 1.1 cm and the total arc length is 25 cm. Although a larger diameter could result in a greater flux of slow atoms, a smaller diameter provides a higher degree of thermal and pressure isolation between the source chamber and the trap chamber, which must be maintained cold and at ultrahigh vacuum. The entrance solid angle for the thermal beam is improved by extending the octupole magnetic field to inside the source chamber. The magnets in the source chamber are made of SmCo because the Curie temperature of this material is high enough to make it possible to retain magnetism while vacuum-baking the magnets along with the chamber. The high-magnetic-permeability yoke material in this design is a 400-series stainless steel. The yokes shunt the field lines, reducing stray fields that might perturb the trap. They also flatten the magnetic-field

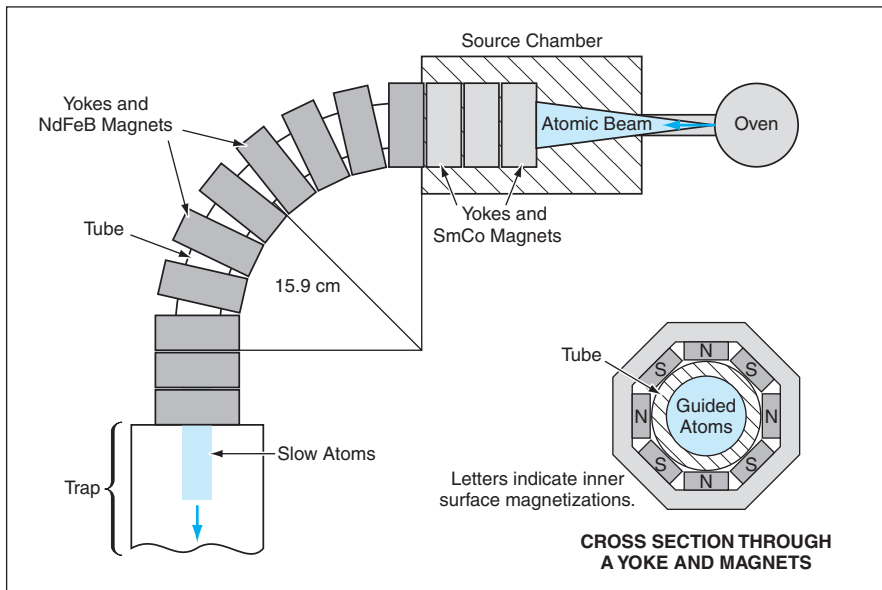
profile, thereby widening the entrance for slow atoms. The yokes also increase the magnetic-field strength by about 50 percent in the guiding region inside the tube and serve as a frame for holding the magnets in the appropriate positions.

According to a proposal, atom skimmers would be utilized as coupling devices in atom-laser systems. An atom laser is a conceptual device, based partly on the concept of a Bose-Einstein condensate, which is a collection of many atoms that have exactly the same energy or, equivalently, are in the same quantum state. Atom lasers would be analogous to optical lasers in some respects. Like beams of laser light, beams of atoms drawn from Bose-Einstein condensates exhibit coherence and interference. Potential systems based on atom lasers could include atomic interferometers as rotation sensors and gravity gradiometers, sources of atoms for precisely controlled deposition, and improved atomic clocks. The role of atom skimmers in atom-laser systems could be analogous to that of optical fibers in optical systems.

The atom-skimmer concept is amenable to miniaturization. The magnetic fields needed for guiding could be generated by magnetic thin films deposited on substrates or by electromagnets in the form of microfabricated wires carrying electric currents. Hence, such systems as atomic interferometers fed by atom lasers and using magnetic guiding of atom-laser outputs could be fabricated with dimensions and by use of techniques similar to those of integrated circuits.

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An Atom Skimmer consists basically of a curved tube surrounded by magnets that generate a multipole magnetic field. Low-velocity atoms are guided along the tube from the source to the trap.