Bright ion beams from laser-cooled atoms

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Since the first experiments in the 1980s, laser-cooled atoms have enabled great progress in many applications, ranging from atomic timekeeping and trace isotope detection to quantum information processing. Recently, cold atoms have seen applications in nanoscale imaging and fabrication in the form of high brightness ion sources. These new sources not only rival conventional ion sources in brightness, but also provide a wide choice of ionic species and a narrow energy spread. The result is a range of new opportunities for creating high resolution focused ion beams (FIBs) for improved ion microscopy, nanoscale milling, implantation, and secondary ion mass spectrometry.

Conventional ion sources generally achieve high brightness by extracting ions from an extremely sharp tip. Cold-atom ion sources achieve high brightness in a very different way: atoms at temperatures in the range of tens to hundreds of microkelvin are photoionized, creating an ion beam with extremely small thermal transverse velocity spread and a corresponding high degree of collimation. Since brightness is inversely proportional not only to source size but also angular spread, this high collimation can result in a large brightness, even though the source is typically much larger in diameter than a conventional sharp-tip source.

So far, cold-atom ion sources have been demonstrated with rubidium,[1] chromium,[2] lithium[3] and cesium[4] ions. The first three of these demonstrations utilized a magneto-optical trap to provide the cold atoms in a configuration often referred to as a magneto-optical trap ion source (MOTIS). This type of source has shown high quality imaging, particularly for the case of lithium, but has a fundamental brightness limit due to the diffusion rate of cold atoms into the ionization region. The cesium source represents the first demonstration of a new approach that employs a two-dimensionally cooled and compressed slow atomic beam, which avoids this limit. In this talk I will review the current state of cold atom ion sources, and discuss prospects for future developments in this rapidly changing field.

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