Atom lithography with Indium and fabrication of *III-V* semiconductor nanostructures

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We work on the direct controlled deposition of Indium because this is a very important process for the production of new *III-V* semiconductor nanostructures in modern industry.

It is possible to control the deposition of atoms on a surface by controlling the atomic flux distribution through the methods of laser cooling and atom optics [1, 2]. This is called Atom Lithography because immaterial light masks work here similar to the masks of resist material in conventional lithography processes. The Indium atomic beam is structured by the

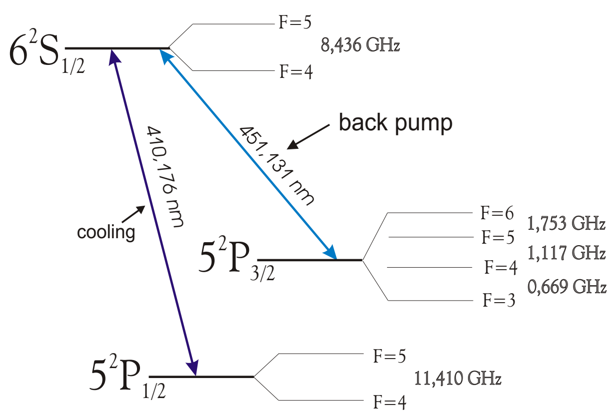

Figure 1: Energy level diagram of Indium.

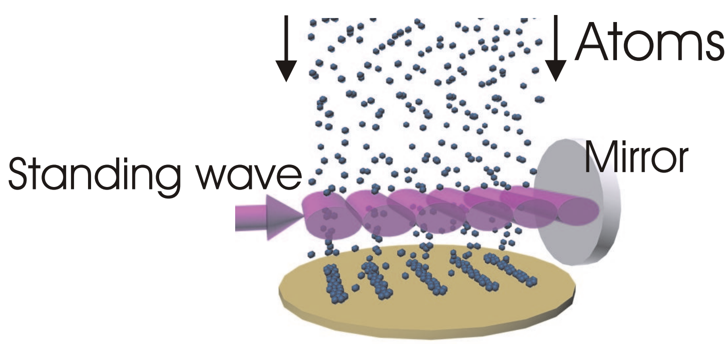

Figure 2: Writing lines with standing wave as a light mask.

optical dipole force in an inhomogeneous near-resonant light field. In the simplest case a plane standing wave with a frequency tuned slightly below (red detuned) or above (blue detuned) the $5^2P_{\frac{1}{2}} \longleftrightarrow 6^2S_{\frac{1}{2}}$ atomic transition (See Fig. 1) forms an array of cylindrical lenses which focuses the atomic beam into a series of straight lines with a width 20-60 nm depending on the intensity of the light field. The spacing between the lines is $\frac{1}{2}$ of the laser wavelength (See Fig. 2). It is possible to write more complicated patterns using more than one standing wave [3].

Before focusing the atoms it is necessary to minimize the transverse component of their velocity by laser cooling (See Fig. 3). For this we use the $5^2P_{\frac{1}{2}} \longleftrightarrow 6^2S_{\frac{1}{2}}$ transition. But after

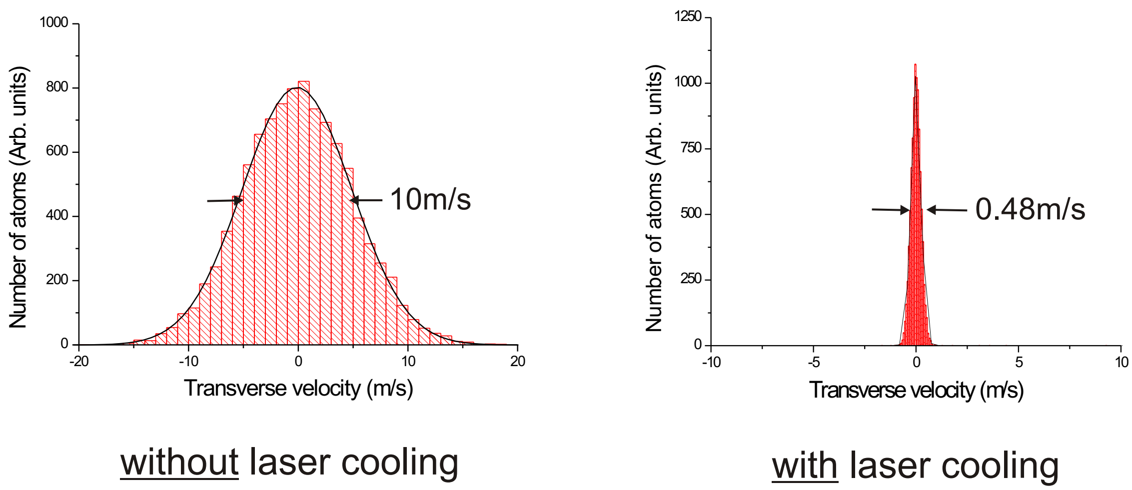

Figure 3: Transverse velocity distribution of the atomic beam without and with laser cooling.

a few cooling cycles all the atoms will be in the $5^2P_{\frac{3}{2}}$ level because the transition probability scales with $2J + 1$, where $J = \frac{1}{2}$ or $\frac{3}{2}$. So we use a frequency-doubled Ti:Sa laser to pump the atoms back into the $6^2S_{\frac{1}{2}}$. To cover the hyperfine structure we use a set of EOM and AOM as

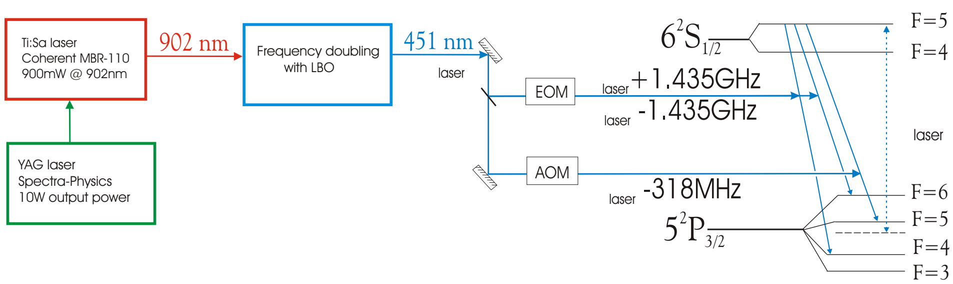

Figure 4: Laser source for back-pump.

shown in Fig. 4.

Depositing several atomic species simultaneously (for example In, Al, As) while spatially modulating only the Indium atomic flux it is possible to create a crystal with controlled modulation of index of refraction in two dimensions. Additional regulation of the flux of the atoms during the crystal growth leads to the modulation of the refractive index in all three dimensions. Varying the the geometry of the light field it should be possible to produce a photonic band gap structure, provided refractive index contrast is high enough [4].

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