A way to improve spot size and resolution in optical projection lithography has been demonstrated in atomic beams using quantum state quenching near the node of an optical field [1]. Recently an extension of this technique has been proposed to directly control the exposure of photo-resist molecules [2]. The exposure sequence consists of three steps. In the first step, a diffraction-limited spot of the photo-resist would be excited. Immediately thereafter, a second incident pulse containing a node at its center would quench the outer parts of this spot, decreasing the spot size below the diffraction limit. In the third step, the remaining excited molecules would react to expose the resist.

To obtain the node in the quenching pulse, one could let the driving field of this pulse be a standing wave. A key property of this standing wave is that its maximum intensity should be much higher than the saturation intensity for de-excitation. With such a high intensity, the region where the intensity of the standing wave is too low to effectively quench excited molecules will be very narrow, and the remaining excited spot will be much smaller than the diffraction limit. The distribution of excited molecules, after quenching by the second pulse, will depend on the intensity of this pulse. Figure 1 shows calculations of point spread functions (PSFs) given by a quenching pulse with a standing wave of different intensities as driving field. With a wavelength of the standing wave on the order of 400 nm and a high maximum intensity (~ 10 W/µm^2), the PSF of excited molecules could be made very narrow and spot sizes on the order of tens of nanometers could possibly be achieved. Such a narrow PSF could be applied to achieve continued scaling of optical lithography into the sub-50-nm regime.

Figure 1: Distribution of molecules in the excited state, after the effects of a quenching pulse. The I_0 is the maximum intensity of the quenching pulse and λ_{st.w} is the wavelength of the standing wave. The molecular cross-section for stimulated emission is assumed to be 10^{-16} cm^2. The higher the intensity of the quenching pulse, the more effectively it will quench excited molecules around the node, leading to a narrower PSF.

REFERENCES:
