Getting very, very blue has researchers at the Technical University Braunschweig (Braunschweig, Germany) very, very happy. Recently, the research group investigating lasing materials for optically pumped deep blue lasers created a solid-state laser by depositing organic thin films on a distributed feedback (DFB) grating to generate emission with selectable wavelengths from 401.5 nm to 434.2 nm. The group used an organic spirobifluorene derivative as the thin-film material and the wavelength was tuned by the grating period of the Bragg reflector.

“Tuning down to the blue edge of 401.5 nm makes this laser an extremely short wavelength organic DFB laser,” explains Thomas Riedl, group leader of the organic and inorganic lasers working group at Technical University Braunschweig. “The results render this spiro compound an excellent candidate for blue-emitting diode lasers.”

These results close a gap in the deep blue spectral range by demonstrating the first amplified spontaneous emission and lasing in that region. Many organic molecules and polymers have been observed to lase in the visible spectrum from the red to the blue, but success has been elusive at the deep blue wavelengths. Although spiro-linked compounds have been used previously as the emitting layers in organic LEDs, lasing had not been demonstrated. The specific chemical structure is an essential element of the laser design because absorption, photoluminescence spectra, and amplified spontaneous emission are critical material properties for any working laser.

A helium-cadmium laser with a wavelength of 325 nm was used to record the photoluminescence spectra, and time-resolved fluorescence was measured with a frequency doubled mode-locked titanium-doped sapphire laser at 388 nm with a rep rate of 78 MHz. The luminescence spectra had a maximum at 422 nm and a half width of 24 nm, and the lifetime of the fluorescence in the photoluminescence maximum was measured at 659 ps. The deep blue laser wavelength was measured with a 1200-lines/mm grating and a resolution of 0.018 nm.

The DFB substrate provides the low threshold operation and wavelength selectable capabilities inherent to resonators based on this approach. The grating period and the refractive index of the gain material determine the lasing wavelength via Bragg reflection within the waveguide. The researchers used a segmented grating with different periods to demonstrate the tuning range; each Bragg grating was prepared by dry etching a thermally grown silicon dioxide layer on a silicon substrate using E-beam lithography. The resulting samples had six segments with different grating periods, each at a 2-mm width and a 100-µm depth. The organic material was deposited at a rate of about 50 Å per minute in a high vacuum of 2 × 10⁻⁶ mbar, with a final thickness of 350 nm.

Optical pumping of the organic DFB laser was done with a pulsed nitrogen laser at 337 nm, a pulse duration of 500 ps, and a repetition rate of 20 Hz. The pump was incident at about 30° and the beam from the pulsed organic laser was emitted from the surface of the thin film and either focused into an optical fiber to couple into spectroscopic instruments or onto a power meter. Amplified spontaneous emission of the thin film material peaked at 418 nm. Moving the pump to different segments of the sample, each with different grating periodicities, allowed the laser to tune over 32.7 nm, from 401.5 nm to 434.2 nm. Gain was insufficient outside this wavelength range to reach the lasing threshold.

The measured laser threshold was 83 µJ/cm² and no saturation was observed up to an output pulse power of 3 W. This laser threshold was measured at a wavelength of 411.7 nm. “Although the gratings are silicon based they could be made on polymers, which would allow the devices to be very cheap, suitable even for single use applications,” explains Riedl. Further studies are in progress on other spiro-lined organic compounds suitable for solid-state lasers as well as other improvements to the laser design. — Michael Brownell