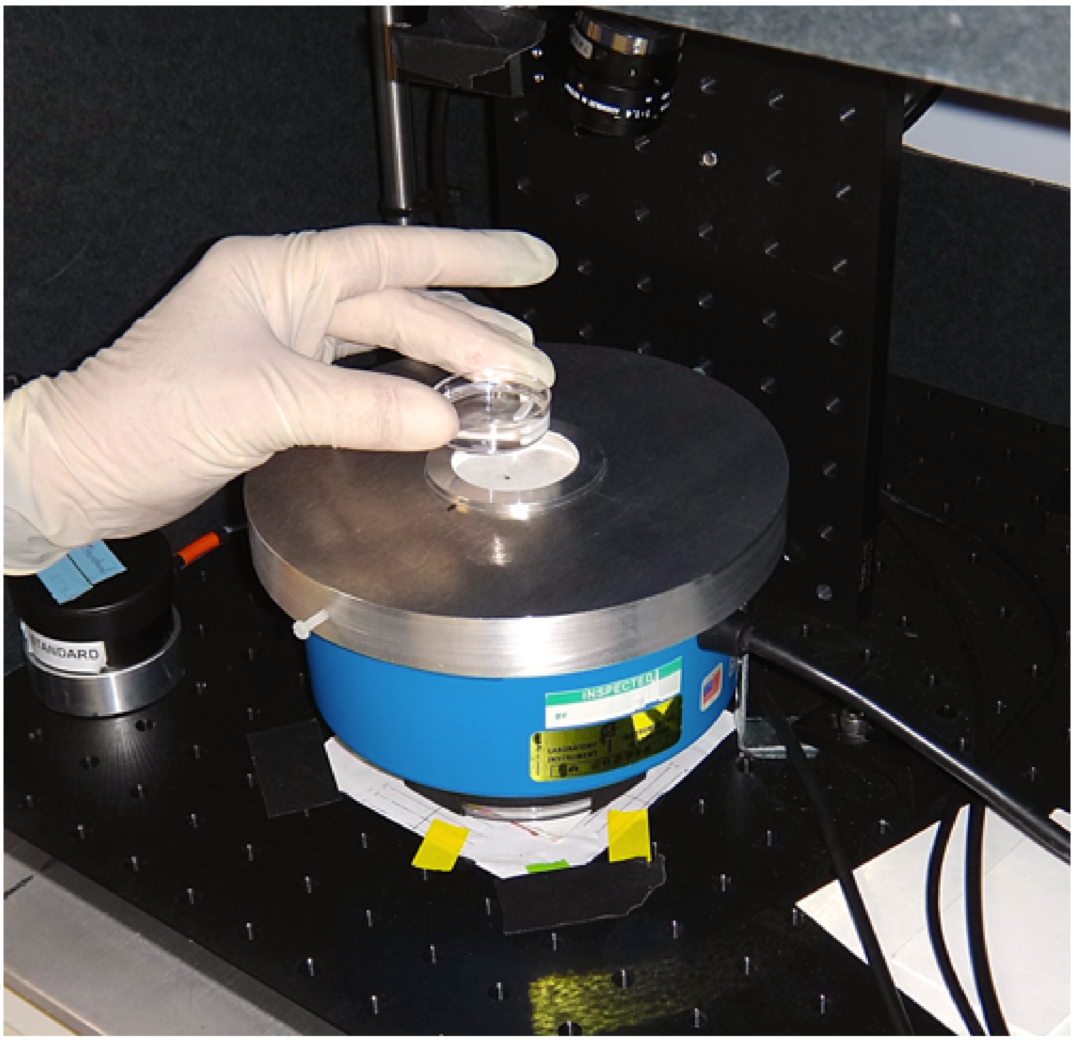
UV ray of hope for safer drinking water

December 24 2012, by Thomas Larason



Placing a water sample for irradiation by UV beams.

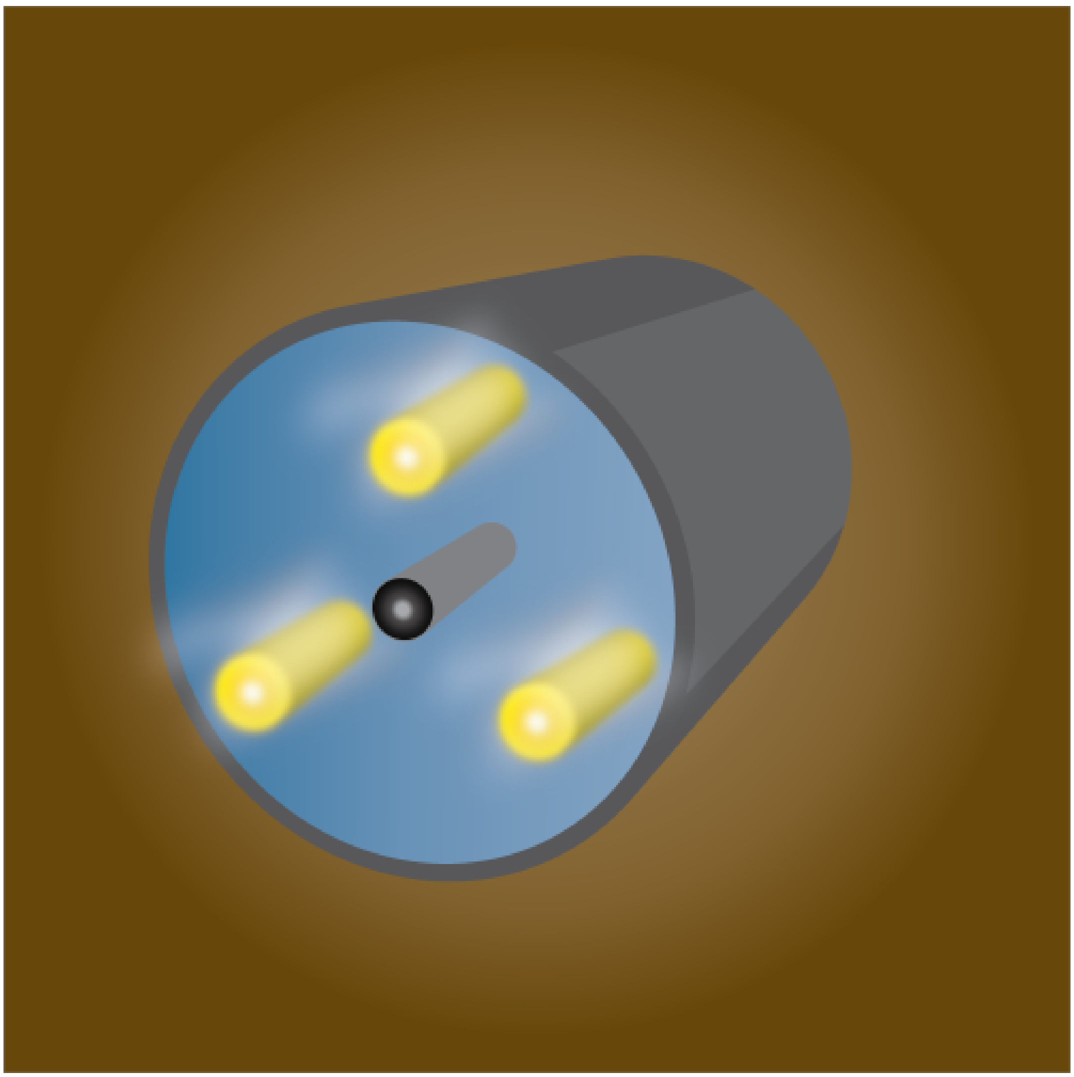
(Phys.org)—A group of researchers from PML's Sensor Science Division is part of a project that will have a direct effect on improved safety of the nation's drinking water.

Recent changes in the Environmental Protection Agency's (EPA) surface water treatment rules mandate, among other things, more aggressive monitoring and control of various pathogens, notably including Cryptosporidium. That microbe, which can cause severe illness or death, is highly resistant to chlorine-based disinfection practices. As one means to reducing the threat, the EPA has called for treating water with ultraviolet (UV) radiation, which also serves as a "secondary barrier" to inactivate (prevent reproduction of) other key pathogens such as adenovirus and other viruses, as well as bacteria and parasites such as Giardia.

The water is treated by cylindrical UV lamps suspended in pipes, and the illumination is monitored by adjacent sensor units. Each pathogen has a different inactivation response to different wavelengths, and it now appears that certain pathogens are most susceptible to wavelengths shorter than the shortest in the spectrum produced by conventional lamps. Recent advances in medium-pressure (MP) UV lamp technology, however, have led to increased UV light output at wavelengths less than 240 nm, prompting researchers to address numerous unresolved questions.

Those questions include: Which wavelengths or combinations of wavelengths (termed "action spectra") are most effective on which pathogens? How much irradiation is required to achieve a "4-log" (99.99%) inactivation for different microbes? How can a new generation of UV sources and sensors be reliably calibrated and validated in water facilities of all sizes across America? And how accurately do benign microbes, used as pathogen surrogates by testing facilities, represent inactivation performance in target microorganisms at different wavelengths?

All those questions and more are under investigation by a multi-organization collaborative project, headed by Karl Linden at the University of Colorado and funded by the Water Research Foundation*, with the goal of eventually developing guidelines for testing future systems using MP mercury vapor lamps as UV sources.



Schematic depiction of lamp and sensor placement in water line. Drawing by Aakash Patel.

"Most of the spectral response data for different pathogens was set up for low-pressure (LP) mercury-vapor lamps as UV sources inside water pipes," says Thomas Larason of NIST's Optical Radiation Group, who leads the PML contribution to the water project. "Those lamps produce a relatively narrow UV spectrum centered on 254 nm, and sometimes referred to as 'germicidal UV' lamps. But the new EPA rules call for higher doses, and attention has shifted to medium-pressure sources, which produce a much broader UV spectrum, including wavelengths below 240 nm, and offer potential energy savings. But the effects of the shorter wavelengths on pathogens have not been well characterized. For some microbes, only a single study has been done until now."

Those data suggest that there is a dramatic disparity in the inactivation of various microbes at different sub-250 nm wavelengths. Earlier this year, a water-project research group charged with studying those effects asked Larason if PML could provide precise UV doses from NIST-calibrated devices to various bacteria and viruses to determine their action spectra. Larason took that request to PML's SIRCUS (Spectral Irradiance and Radiance Responsivity Calibrations Using Uniform Sources) facility, which employs continuously tunable lasers as irradiation sources. Within a short time, SIRCUS staff took a portable laser and associated apparatus to the project test lab in Vermont for studies scheduled to conclude at the end of this year.

The SIRCUS equipment emits radiation from 210 nm throughout the experimental range of interest in the form of a nearly collimated beam that strikes the microbial samples, which are kept in Petri dishes placed below the beam exit.

"At this stage," Larason says, "we're providing the equipment and expertise to help the project find the real dose-response characteristics for different microbes at short wavelengths. Among other things, that will determine how much power you need in the MP lamp, which in turn influences energy costs. After that, we might end up getting involved in devising calibration and validation standards for sources and sensors in the range of 200 nm to 300 nm. But it's too soon to say where all this will lead."

It is not, however, too soon for the American Water Works Association to express its appreciation. In a September 2012 letter to PML Director Katharine Gebbie, the association praised the "unique expertise and tools" brought to the project by Larason along with Keith Lykke, Steven Brown, Ping-Shine Shaw, and Mike Lin of SIRCUS. Their work "is providing information critical to our understanding of pathogen inactivation by low-wavelength UV spectrum" that will "define treatment design for medium-pressure UV treatment in drinking water across the United States," the letter said.

Thanks to the contribution of the NIST researchers and SIRCUS equipment, the collaboration has determined the wavelength responsivity of specific pathogens and associated surrogates with greater accuracy.

"Using NIST's tunable UV laser, we have developed the gold standard on measuring the wavelength response of test microbes and waterborne pathogens for UV disinfection applications across the US," says Harold Wright of Carollo Engineers, Inc. in Boise, ID, a contributor to the research project. "I have worked with Tom Larason and the folks from NIST on two UV disinfection projects sponsored by the Water Research Foundation. With both projects, they brought to the table a level of expertise in the application and measurement of ultraviolet light that is unparalleled in our industry."

The collaboration may also have repercussions beyond the issue of drinking-water safety. "It expands current research areas with minimal investment in new equipment and manpower," Larason says. "But it is also applicable beyond microbiology to other technological areas such as material processing (UV curing), medical (testing devices that measure UV exposure), and expanded calibration capabilities for irradiance and dose."

Provided by National Institute of Standards and Technology