NEXT GENERATION DEEP UV (NGDUV) LASERS FOR ASTROBIOLOGY LANDER INSTRUMENTS.

W. F. Hug[1] and R. D. Reid[2], [1]Photon Systems, Inc., 1512 Industrial Park St., Covina, CA 91722-3417, w.hug@photonsystems.com, [2]Photon Systems, Inc., 1512 Industrial Park St., Covina, CA 91722-3417, r.reid@photonsystems.com.

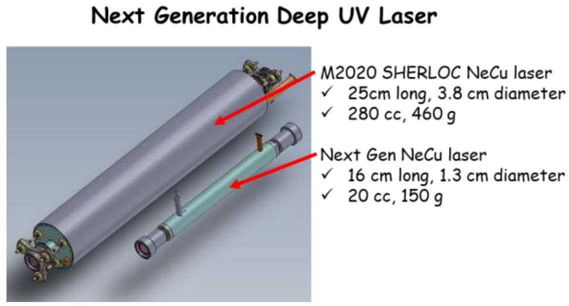
Introduction: This paper addresses the need for a next generation deep UV (NGDUV) laser for application to detection and spatial chemical mapping of trace amounts of organic, pre-biotic, and biological material as well as inorganic compounds and water embedded in a mineral matrix using non-contact deep UV resonance Raman and native fluorescence spectroscopy. The benefits of this method have been demonstrated on the Mars2020 SHERLOC instrument, planned for launch to Mars in July or early August 2020. The NGDUV laser addresses the need of increasingly miniaturized, higher power, next generation chemical and astrobiological detection instruments for Flagship lander missions to "Ocean Worlds" of the outer Solar System and small to medium class Discovery/New Frontiers lander missions to primitive bodies, Dwarf Planets and asteroids such as Ceres, Vesta and others of the nine major Tholen groups of asteroids, moons of Mars Phobes/Demos, comets, Trojans, and Kuiper belt objects. Detection of organics, prebiotic, and biological material and water/ice and their spatial distribution within a substrate matrix are fundamental capabilities required to meet NASA strategic goals a*s indicated by the July 2013 Mars 2020 Science Definition Team (Mustard, et al 2013), "Deep UV fluorescence is a means by which sensitive organic detection and mapping can enable sample selection for Mars".*

Deep UV Laser Requirements

Because of its operation on the arm of a typical rover, the NGDUV laser cannot employ any survival heaters, coolers, or temperature regulation and must operate at ambient temperatures ranging from as low as about 50^0K to 350^0K. It must have a very narrow and stable emission linewidth independent of ambient temperature but preferably less than 1 cm-1 to enable accurate Raman spectroscopy without added size and weight for calibration facilities. Preferably this laser should be unpolarized to enable Raman detection of crystalline material of unknown orientation. It must also provide low peak and average power levels to avoid any thermal or photochemical damage or spectroscopic altering of targeted material. The NGDUV laser should be insensitive to hard radiation (rad-hard) and be able to survive the severe shock and vibration expectations through the entire mission envelope. And finally, the NGDUV laser should have a minimum size, weight, and power consumption (SWAP) including any warm-up or start-up time power consumption.

To satisfy these requirements we are developing a new, higher power, lower SWAP, design of a transverse excited hollow cathode (TEHC) NeCu laser as an extension of the present Mars 2020 SHERLOC laser and based on the knowledge and experience gained in developing and certifying the laser employed in the SHERLOC instrument. The SHERLOC laser has been demonstrated to provide significantly higher peak and average power than originally planned or needed. In fact, the most difficult Raman spectra are being obtained with nearly 10 times lower energy per laser pulse and fewer number of pulses than originally expected. This excessive performance and the opportunity to achieve similar spectral results in a much smaller laser package has led to the need for the NGDUV laser.

Figure 1. Illustration of SHERLOC vs NGDUV lasers



The SHERLOC laser demonstrated the linewidth and stability of the TEHC NeCu laser, less than about 0.10 cm-1, corresponding to about 0.05 nm at the emission wavelength of 248.6 nm. This inherent stability eliminates the need for complicated methods of spectral calibrations for systems using lasers which drift in output wavelength as a result of changing ambient temperatures, etc. The SHERLOC laser was also demonstrated to perform after direct submersion into a bath of liquid nitrogen at 77^0K, without any post-submersion alignment. And, because of basic construction of the NeCu laser, there is no inherent reason that it cannot operate at temperatures below about 25^0K without preheating or temperature regulation. In addition, the NeCu laser output commences within about 10 µs of application of power, independent of ambient temperature. This eliminates lengthy warm-up time and related energy consumption per operational sequence. The output of the laser is randomly polarized, enabling Raman spectra to be collected from crystalline target material with unknown crystal lattice orientation. Further, because the pulse width of this laser is about 40 µs, the peak power is low, essentially eliminating any thermal heating of targeted samples which commonly occurs with harmonic generated laser with pulse widths of a few ns. And because of the short excitation wavelength, the full Raman and fluorescence spectra of organic materials are excited, without fluorescence interference of the Raman spectra or Raman interference of the fluorescence spectra. The combination of these two spectral detection modes enables very sensitive detection and identification of organic, pre-biotic, and biological material as well as minerals and water/ice. Similarly, the short excitation wavelength provides resonance Raman signal enhancements for organic and biological material. The NeCu laser is inherently Rad Hard since there are no components of elements damaged by high energy ionizing radiation such as expected on Europa. The NeCu laser was also demonstrated to be easily capable of withstanding many times the required shock and vibration specifications for missions similar to the Mars 2020 lander mission.

During the SHERLOC laser development program, we learned that operating the laser at much higher pulse repetition frequency (PRF) enabled better Raman or fluorescence spectra to be accumulated faster with less dark noise. We also learned that the SHERLOC laser was capable of much higher PRF without significant loss of output energy per pulse. The SHERLOC laser was initially operated at only about 10 Hz. But eventually, the SHERLOC laser was operated at 80 Hz in its final launch condition. It could probably have operated at much higher PRFs, but the laser was already providing much higher power levels than was needed, by a factor of 10X or more. This excessive performance and the opportunity to achieve similar spectral results in a much smaller laser package has led to the NGDUV laser. Fig. 1 above show a comparison of the SHERLOC and Next Generation NeCu laser

References:

[1] L. W. Beegle[1], R. Bhartia[1], L. DeFlores[1], W. Abbey[1], E. Miller[1], Z. Bailey[1], J. Razzell Hollis[1], R. Pollack[1], S. Asher[2], A. Burton3, M. Fries[3], P. Conrad[14], S. Clegg[5], K. S. Edgett[6], B. Ehlmann[7], W. Hug[8], R. Reid[8], L. Kah[9], K. Nealson[10], T. Nelson[5], M. Minitti[11], J. Popp[12], F. Langenhorst[12], C. Smith[15], P. Sobron[13], A. Steele[14], N. Tarcea[12], R. Wiens[5], K. Williford [1], R. A. Yingst[11]. [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena Ca, 91109 Luther.Beegle@jpl.nasa.gov),[2]University of Pittsburgh, [3]Johnson Space Center, [4]Goddard Space Flight Center, [5]Los Alamos National Laboratory, [6]Malin Space Sciences, [7]California Institute of Technology, [8]Photon Systems Inc., [9]University of Tennessee, [10]University of Southern California, [11]Planetary Science Institute, [12]University Of Jena, [13]SETI Institute, [14]Carnegie Institute Washington, 15 Natural History Museum, London. "The SHERLOC Investigation on the Mars 2020 Rover", Lunar Planetary Science Conference, March 16, 2020, Woodland, TX.

[2] Bhartia, R., L.W. Beegle, J. Hollis, B. Cameron, B. Monacelli, D.A. Nordman, E. Eshelman, A. Abbey, Y. Wu, R. Hodyss, L. DeFlores, W. Hug, R. Reid, R. Weins, and T. Nelson, "SHERLOC-E: Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals for Europa Lander", Instr. f. Planetary Missions (IPM2018), Berlin, Germany, Sept. 12-14, 2018.

[3] Abbey, W.J., R. Bhartia, L. Beegle, L. DeFlores, V. Paez, K. Sijapati, S. Sijapati, K. Williford, M. Tuite, W. Hug, and R. Reid, "Deep UV Raman spectroscopy for planetary explorations: The search for in situ organics", Icarus 290 (2017) 201-214.

[4] Bhartia, R., K. Williford, R. Reid, W. Hug, K. Sijapati, V. Paez, L. DeFlores, M. Tuite, S. Sijapati, L. Beegle, and W. Abbey, "Deep UV Raman Spectroscopy for Planetary Exploration: The Search for In-Situ Organics", Icarus, Elsevier, Dec. 2016

[5] Beegle, L.W., R. Bhartia, L. DeFlores, E. Miller, R. Pollack, W. Abbey, S. Asher, A. Burton, B. Carrier, M. Fries, P. Conrad, S. Clegg, K.S. Edgett, B. Ehlmann, W. Hug, R. Reid, L. Kah, K. Nealson, T. Nelson, M. Minitti, J. Popp, F. Langenhorst, V. Orphan, M.A. Ravine, P. Sobron, A. Steele, N. Tarcean, G. Wanger, R. Weins, K. Willingord, R.A. Yingst, "Characterization and Development of the SHERLOC Instrument for Mars 2020", 2015 American Geophysical Union, San Francisco, CA, 15 Dec. 2015.