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Creating a Better Source of 118 nm Light By Frequency Tripling with a Novel Xenon-Argon Mixture

Abstract:
The goal of my project is to create a better source of 118nm laser light (118) by frequency tripling 355nm light with a Xenon-Neon mixture. At high intensities of incident 355 nm light (355), a Xenon-Neon mixture could be much more efficient at producing 118 than the current Xenon-Argon mixture. The new gas system would give physicists that use 355 ND:YAG lasers a more intense source of 118nm light for their experiments.

Prospectus:
Cold molecule physics labs use 118 nm light for single photon ionization mass spectrometry, a popular and useful technique that effectively ionizes molecules [1,2]. A common way of producing 118 is by frequency tripling 355 with a Xenon-Argon mixture. The major limitation of the Xenon-Argon mixture is that it cannot produce 118 at high intensities of incident 355, likely for one of two reasons. First, two absorption lines in Xenon at 117nm and 119nm are pressure broadened as the partial pressure of Xenon increases [3], leading to absorption of the 118 by Xenon atoms. Our lab has calculated that pressure broadening from the 119nm line could be significant enough to lead to 118 absorption by Xenon. Second, the buffer gas could be reabsorbing some of the output 118 in a second harmonic process. Buffer gases are used to ensure that output light waves constructively interfere, in a process called phase matching [4]. Xenon triples the incident 355 nm light into 118 and Argon is used as the buffering gas to phase-match the output 118 with the 355 nm light [5]. As the input 355 intensity increases, the amount of 118 emitted by the Xenon atoms increases as well. The abundance of 355 and 118 within the mixture means there is a greater chance an atom of Argon gas can absorb both the 355 and 118 simultaneously and then emit 88nm light in a second harmonic process. Although second harmonic generation (SHG) would normally not be possible in an isotropic medium like gaseous Argon, SHG has been observed when photoionization of a gas induces an electric field that breaks the symmetry of the gas. [6,7] This absorption of 118 and emission of 88 nm light by Argon would explain the drop in 118 generation at high intensities of incident 355 nm light in the Xenon-Argon source. Our group hypothesizes that Neon, unlike Argon, would provide phase

matching without reabsorbing the 118 because Neon's energy levels do contain an absorbance line capable of absorbing a combination of 118 nm and 355 nm light [8]. Since a Xenon-Neon 118 source would not reabsorb 118, it would be efficient at high intensities of incident 335. A novel Xenon-Neon system would offer physicists investigating atoms or molecules more 118 nm light for UV spectroscopy than the current Xenon-Argon system.

Since the beginning of 2017, I have taken steps to determine the issue limiting 118 production in the existing Xenon-Argon source. First, I built an experimental setup that will allow me to measure how much 118nm light is generated from a gas source. I am using this setup to test the existing Xenon-Argon 118 source to establish a control that I can compare to the new gas systems I will build. Finally, I will try to find the factor limiting 118nm light generation for high Xenon pressures. To test if pressure broadening of the 117nm and 119nm Xenon lines has caused 118nm light to be linearly absorbed by Xenon, I will construct a gas cell adjacent to the Xenon-Argon 118 source and gradually add in Xenon. By comparing the 118 signal before adding Xenon into the cell to the 118 signal after adding Xenon into the cell, I will be able to determine if linear absorption in Xenon is the primary issue. If linear absorption in Xenon is not the problem, I will determine if SHG in Argon is the limiting factor. To do this I will build the new Xenon-Neon system and measure how much 118 it can produce. I will compare the original Xenon-Argon 118 source to the new Xenon-Neon source to see if the new source produces more 118, which would indicate SHG in Argon is the limiting factor. To measure the amount of 118 I produce, I will first ionize a packet of deuterated ammonia (ND3) molecules using resonance enhanced multi-photon ionization (REMPI). I will then use time of flight mass spectroscopy (TOFMS) to determine the amount of ionized ND3. The measured amount of ionized ND3 will correspond to the amount of incident 118. REMPI and TOFMS are the measuring tools I will use to determine if linear absorption in Xenon or SHG in Argon is the limiting factor in 118 production. If SHG in Argon is the issue, the new Xenon-Neon source will hopefully produce more 118.

Bibliography:

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[7] Bethune, D. S. “Optical second-Harmonic generation in atomic vapors with focused beams.” Physical Review A, vol. 23, no. 6, Jan. 1981, pp. 3139–3151., doi:10.1103/physreva.23.313
[8]“Electron-Impact Excitation out of the Ground State of Atoms.” Electron-Impact Excitation out of the Ground State of Atoms, University of Wisconsin- Madison, 10 June 2008, raptor.physics.wisc.edu/talk/neon_e.gif.

Other Possible Sources:

[8] “Influence of nonlinear susceptibility of a buffer gas on third harmonic generation,” S. A. Batishche et al, Soviet Journal of Quantum Electronics Vol. 10 Num. 10 (1980)
[9] “Attenuation of vacuum ultraviolet light in pure and xenon-doped liquid argon —An approach to an assignment of the near-infrared emission from the mixture,” A. Neumeier et al, EPL Journal 111 12001 (2015)
[10]”Third-harmonic generation at atmospheric pressure in methane by use of intense femtosecond pulses in the tight-focusing limit,” G. Marcus, A. Zigler, Z. Henis, J. Opt. Soc. Am. B Vol. 16, No. 5 (1999)
[11]“1+1′ resonant multiphoton ionisation of OH radicals via the $A^2\Sigma^+$ state: insights from direct comparison with A-X laser-induced fluorescence detection,” J. M. Beames, F. Liu, M. I. Lester Molecular Physics Vol. 112 , Iss. 7 (2014)

Timeline

October:

Lab goals:

I plan to finish testing the existing Xenon-Argon Source before October 3rd. I will then build the Xenon cell to determine if pressure broadening is the limiting factor. I plan to finish my pressure broadening test by October 15th.

Writing Goals:

1.) I will turn in my honors thesis packet before Tuesday October 3rd.
2.) I will begin writing the background section of my thesis.

November:

Lab goals:

If pressure broadening is the problem, I will consider ways to limit pressure broadening from my source. If not, I will then consider SHM to be the problem and build a Xenon-Neon source.

Writing goals:

I will continue writing the background section of my thesis. I will begin writing my experimental results section now that I have the pressure broadening data.

December:

Lab Goals:

If pressure broadening was the issue, I will continue to try to find a way to limit the pressure broadening effect. If SHM is the issue, I will test the Xenon-Neon source.

Writing Goals:

I will finish writing the introduction and background and include the experimental results I have.

January:

Lab Goals:

I plan to finish all experimental testing by the end of January/early February.

February:

Writing Goals:

I will finish the first draft of my thesis and begin editing and proofreading. I will go over draft at least once with my advisor before February 15th.

Presentation Goals:

I plan schedule one practice talk in February and one in March.

March:

I will make final revisions to my thesis.