**John C. Wright**

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July, 2024

Dear Editor,

We enclose a manuscript entitled *Coherent Hyper-Raman Four Wave Mixing Vibrational Spectroscopy,* authored by Ryan P. McDonnell, Daniel D. Kohler and John C. Wright for consideration as a publication in *The* *Journal of Chemical Physics* as part of the Y. Ron Shen Festschrift.

The corresponding author is:

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Four wave mixing (FWM) spectroscopies are largely known for their ability to dissect vibrational anharmonicity in large and small molecular species. These methods resolve anharmonic coupling though infrared (2D-IR) and infrared/Raman (Doubly Vibrationally Enhanced) pathways. These methods were based upon coherent anti-Stokes Raman spectroscopies (CARS) developed in the 1970 and 1980’s. Similarly, three wave mixing (TWM) methods resolve interfacial vibrational spectroscopy and dynamics through infrared/Raman pathways (sum frequency generation). A seldom used type of transition which could increase the specificity of nonlinear spectroscopy are hyper-Raman transitions. However, unlike CARS, the coherent analogue of pure hyper-Raman spectroscopy is a six wave mixing technique, which is virtually impossible to resolve in the laboratory due to lower order, four wave mixing cascades that complicate output. The only example of an infrared/hyper-Raman type method was developed in our laboratory decades ago to demonstrate the feasibility of four wave mixing involving solely vibrational transitions but has not been investigated in detail for over twenty years.

\*CMDS is important and FWM is used to isolate vibrational coupling

\*TWM good for spectroscopy and dynamics – FWM doesn’t have something similar really other than CARS; SIVE comes in and provides upconverted IR spectroscopy

\*SIVE ends up resolving vibronic coupling akin SFG in isotropic systems; unique analogue of hyper-Raman methods

\*Implementation of coherent hyper-Raman == SWM; we have FWM analogue => minimal cascades.

The major innovations of our paper are:

1. Identification of Singly Vibrationally Enhanced (SIVE) spectroscopy as the coherent four wave mixing analogue of hyper-Raman spectroscopy. This bypasses the need for six wave mixing techniques
2. We show how quantitative analysis of SIVE spectra can resolve the hyper-Raman polarizability *via* the interferometric technique developed by Levenson and Bloembergen.
3. We demonstrate that SIVE spectroscopy is, on average, brighter than its second order analogue, sum frequency generation spectroscopy, making it a feasible method for interpreting isotropic spectra of most vibrational species.

We believe this manuscript highlights the versatility of mixed time-frequency domain methods as a probe of molecular structure and will be of great interest to the readership of *The Journal of Chemical Physics*. This work has a direct impact on the development of multidimensional spectroscopies and provides new methods for investigating vibronic coupling in molecular species. We believe this work will encourage the implementation of mixed time-frequency domain methods for probing noncovalent interactions and ultrafast dynamics in material and biomolecular systems, chemical reactions, and probing vibronic coupling in complex molecular systems.

Sincerely,

A close-up of a black handwritten letter

Description automatically generated

John C. Wright

Andreas C. Albrecht Professor of Chemistry

University of Wisconsin - Madison

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P.S. We suggest the following reviewers:

**Prof. David A. Blank**

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Reason: Prof. Blank is an expert in the application of mixed vibrational/electronic spectroscopies.

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**Prof. Minhaeng Cho**

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Reason: Prof. Cho is an expert in the theory of the coherent multidimensional spectroscopies discussed in this manuscript.

**Dr. Paul M. Donaldson**

Senior Scientist

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Email: [paul.donaldson@stfc.ac.uk](mailto:paul.donaldson@stfc.ac.uk)

Website: [www.clf.stfc.ac.uk/Pages/paul\_donaldson\_ukri\_fellow.aspx](http://www.clf.stfc.ac.uk/Pages/paul_donaldson_ukri_fellow.aspx)

Reason: Dr. Donaldson is a pioneer and expert in the application of coherent Raman spectroscopies to biomolecular samples.

**Prof. James Gaynor**

Department of Chemistry

Northwestern University

Email:

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Reason: Prof. Gaynor is a pioneer and expert in the application of time domain vibrational-electronic spectroscopies.

**Dr. Maksim Grechko**

Max Planck Institute for Polymer Research

Email: [grechko@mpip-mainz.mpg.de](mailto:grechko@mpip-mainz.mpg.de)

Website: <https://www.mpip-mainz.mpg.de/en/bonn/groups/grechko>

Reason: Dr. Grechko is an expert in the design and application of the coherent multidimensional spectroscopies discussed in this manuscript.

**Prof. Anne Myers Kelley**

School of Natural Sciences

University of California – Merced

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Reason: Prof. Myers Kelley is a pioneer and expert in the application and theory of resonance Raman and hyper-Raman spectroscopy to condensed phases.

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**Prof. Patrick Vaccaro**

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Reason: Prof. Vaccaro is an expert in the application and theory of coherent four wave mixing spectroscopies.

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**Prof. Lawrence D. Ziegler**

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Reason: Prof. Ziegler pioneered gas phase resonance hyper-Raman spectroscopy.