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Final Report: Correlation Interferometry and Time-resolved Spectroscopy to Elucidate the Origins of Radiation Brightening in Viromimetic Particles

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Approved for public release; distribution is unlimited.

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14. ABSTRACT

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RPPR Final Report
as of 07-Sep-2022

Agency Code: 21XD

Proposal Number: 75692MSRIP **Agreement Number: W911NF-20-1-0071**
INVESTIGATOR(S):

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Report Date: 14-Mar-2022 Date Received: 18-Aug-2022
Final Report for Period Beginning 15-Jun-2020 and Ending 14-Dec-2021
Title: Correlation Interferometry and Time-resolved Spectroscopy to Elucidate the Origins of Radiation Brightening in Viromimetic Particles
Begin Performance Period: 15-Jun-2020 **End Performance Period:** 14-Dec-2021
Report Term: 0-Other

Submitted By: Bogdan Dragnea Email: dragnea@indiana.edu
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Distribution Statement: 1-Approved for public release; distribution is unlimited.

STEM Degrees: **STEM Participants:**

Major Goals: The main goal of the project was to construct a comprehensive spectroscopic analysis system, including photon statistics with a Hanbury Brown and Twiss interferometer, single-particle fluorescence life- time with a 25 ps resolution spectrometer, and transient absorption spectroscopy through the upgrade and inclusion of a set-up available in the lab. In addition, we proposed to construct an optical levitation chamber, which will made possible spectroscopic investigations of single particles free of substrate and solvent interference.

Accomplishments: All goals mentioned in the previous section were accomplished. Instrumentation was constructed and is operational. Research has begun and first results have been disseminated in three research papers.

Training Opportunities: During the reporting period three graduate students, one undergraduate, and 2 high school students were trained on the instrument. One graduate student has earned their Ph. D' degree and one student a Master's degree.

Results Dissemination: The PI has presented results of investigations using the instrumentation at invited talks at two institutions (UCLA and U Delaware).
Students have presented five posters and gave 2 talks at national meetings.
Five research papers including data acquired with the instrument were published in peer review journals so far..
Research Communications -- an Indiana University media outlet published a story describing the work: https: //research.impact.iu.edu/more-iu-research/stories/bogdan-dragnea-laboratory.html
U.S. patent application number 16/545301 was filed with the patent office on 2020-02-20 for virus-enabled targeted vector for imaging.

Honors and Awards: 2020 Carolyn & Charles Knobler Lectureship at UCLA

Protocol Activity Status:

Technology Transfer: U.S. patent application number 16/545301 was filed with the patent office on 2020-02-20 for virus-enabled targeted vector for imaging.

PARTICIPANTS:

RPPR Final Report
as of 07-Sep-2022

Participant Type: High School Student
Participant: Jason Thiagarajan
Person Months Worked: 1.00 **Funding Support:**
Project Contribution:
National Academy Member: N

Participant Type: Staff Scientist (doctoral level)
Participant: Irina Tsvetkova
Person Months Worked: 1.00 **Funding Support:**
Project Contribution:
National Academy Member: N

Partners

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I certify that the information in the report is complete and accurate:
Signature: Bogdan Dragnea
Signature Date: 8/18/22 11:33AM

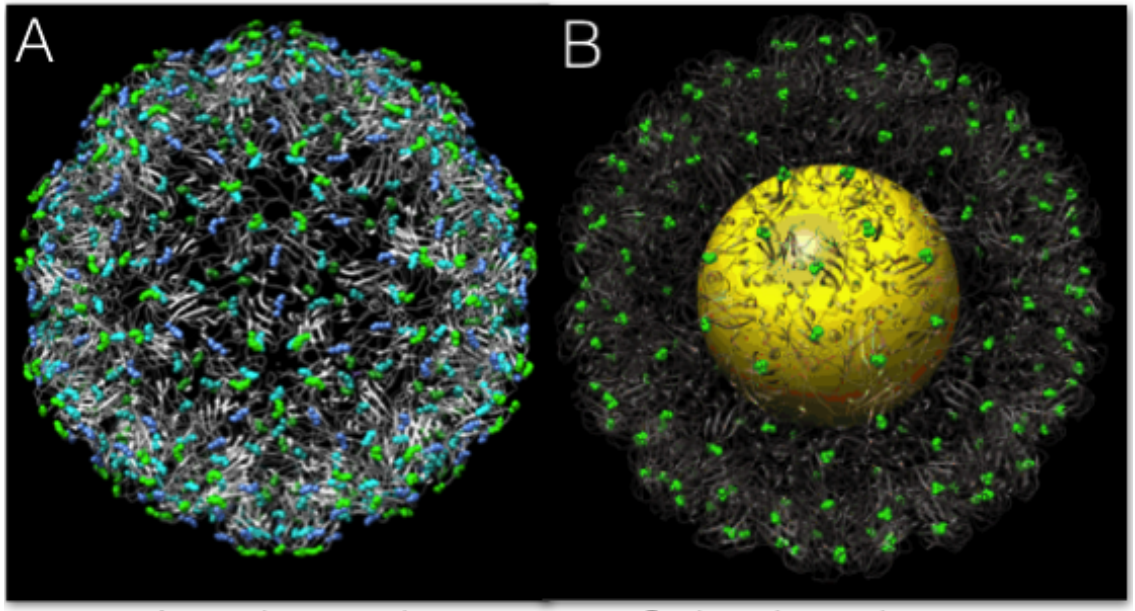
Coherent Bio-nanomaterials

PI: Bogdan Dragnea

August 28, 2021

Current Objective

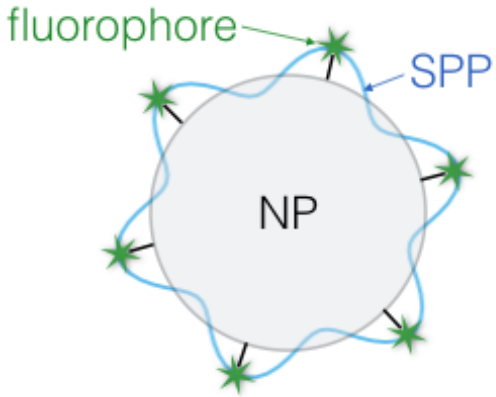
Harness the structural fidelity and mechanical properties of self-assembled virus-like particles (VLPs) to control collective relaxation dynamics after photoexcitation.



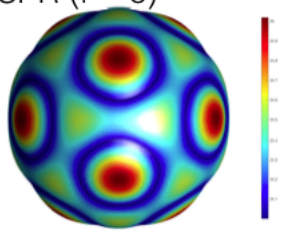
$$I_{coherent} \sim N^2$$

Target applications

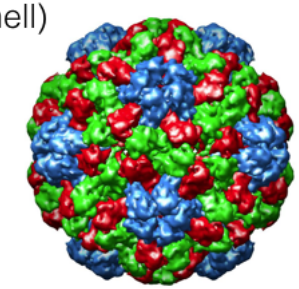
- Deep sub-wavelength, intense light source ⇒ Photonics, biomedical applications e.g. sentinel lymph node imaging, laser-assisted surgery.
- Enhanced plasmon coupling ⇒ Hot electrons for photocatalysis.



On nanoparticle:
SPR (l = 6)



Around the nanoparticle:
(T=3 shell)

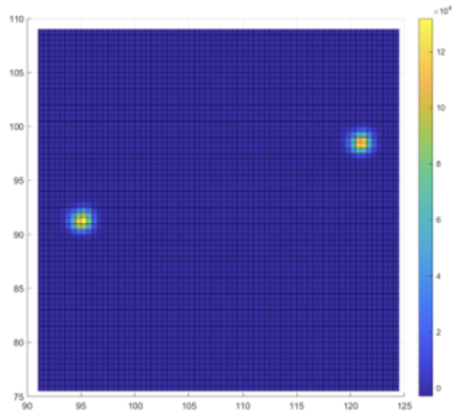


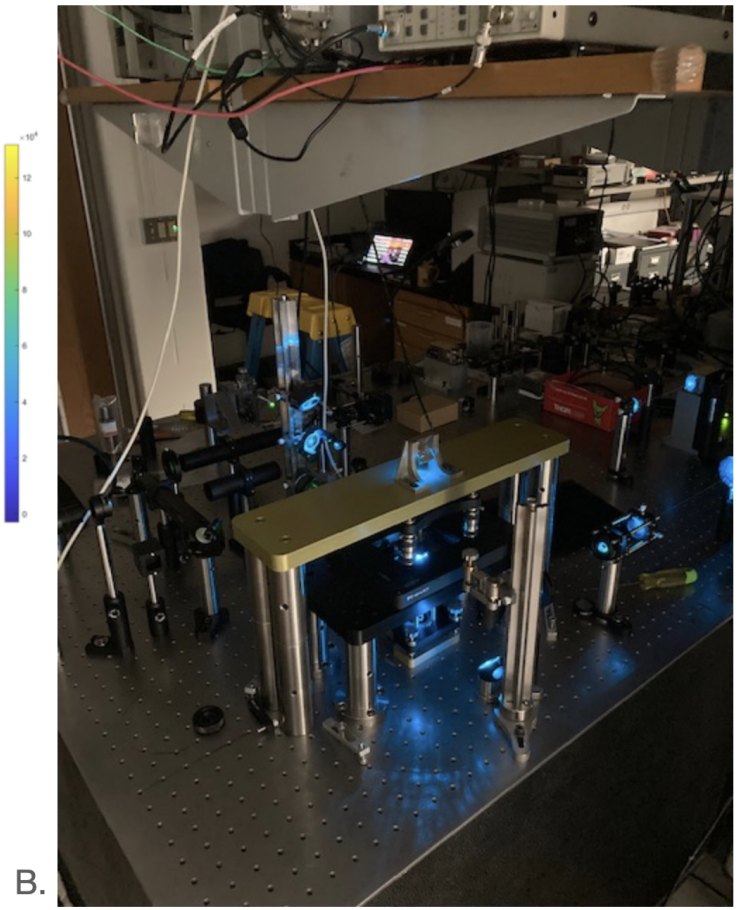
$$Y_h(6) = Y_{6,0}(\theta,\phi) + \sqrt{\tfrac{7}{11}}Y_{6,5}(\theta,\phi) - \sqrt{\tfrac{7}{11}}Y_{6,-5}(\theta,\phi)$$

Overview of Goals and Achievements

- Complemented time-resolved fluorescence data acquired at the Advanced Photon Source (APL) with transient absorption spectroscopy to determine the relaxation pathways after excitation. A new relaxation channel opens by fluorophore coupling at high labeling densities. Manuscript in internal review.
- Extending wavelength range and exploring the mechanistic role of intermolecular interactions. Xanthenes (OregonGreen) , boron-dipyrromethene (BDipy), and cyanine dyes. Discovered that virus shells can be assembled in an aprotic organic solvent if it is polar and can H-bond with water. Manuscript submitted.
- Studied collective light absorption by dye-VLPs encapsulating a plasmonic NP. Significant absorption cross-section enhancement observed. Currently repeating experiments to reproduce the result.
- Most of the photon correlation microscope is done. GUI, scanning and DAQ software written in MATLAB. Currently testing noise, background, mechanical stability, spatial and temporal resolution.

Photon correlation microscope setup

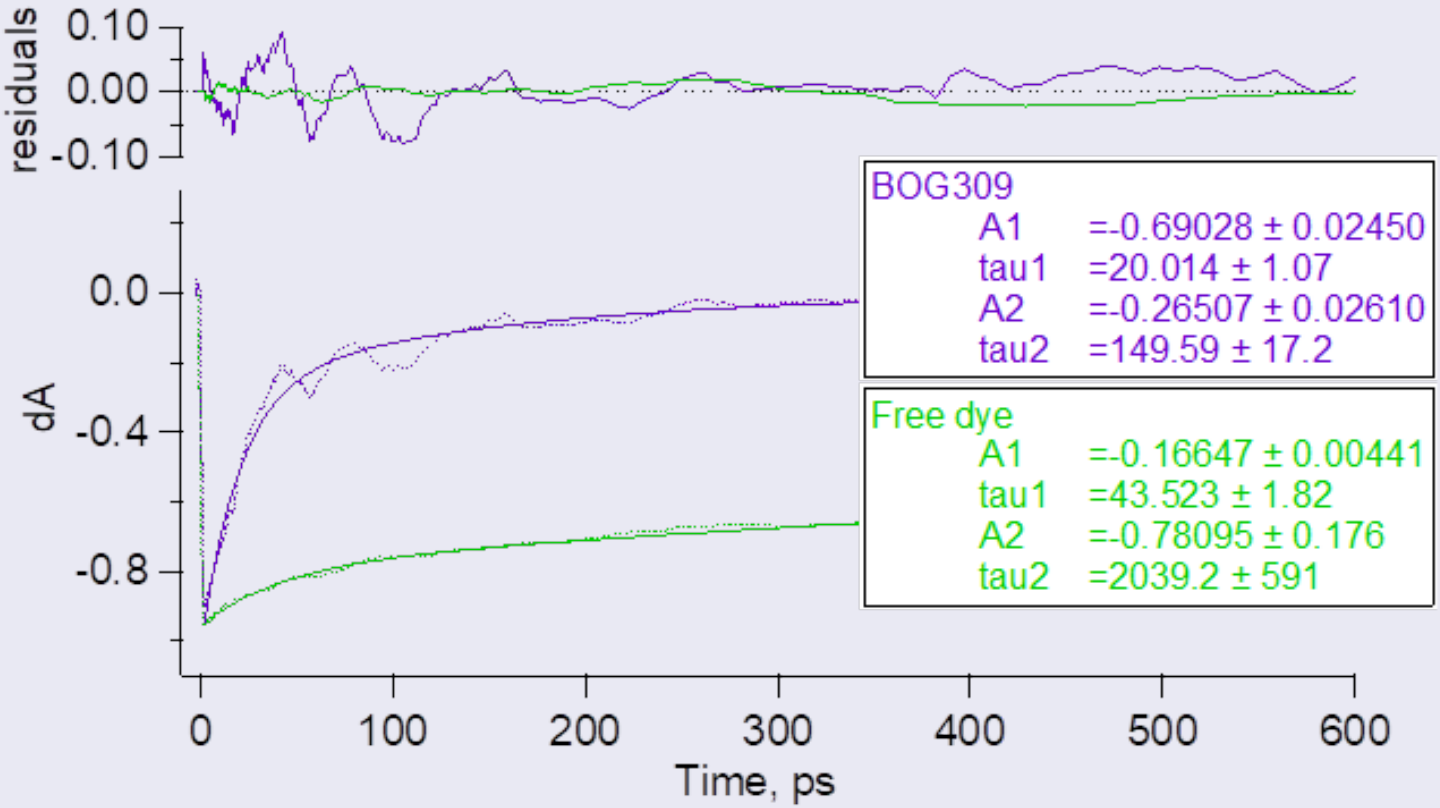




A. Confocal scanning of fluorescent beads on glass. B. Partial view of the optical setup.

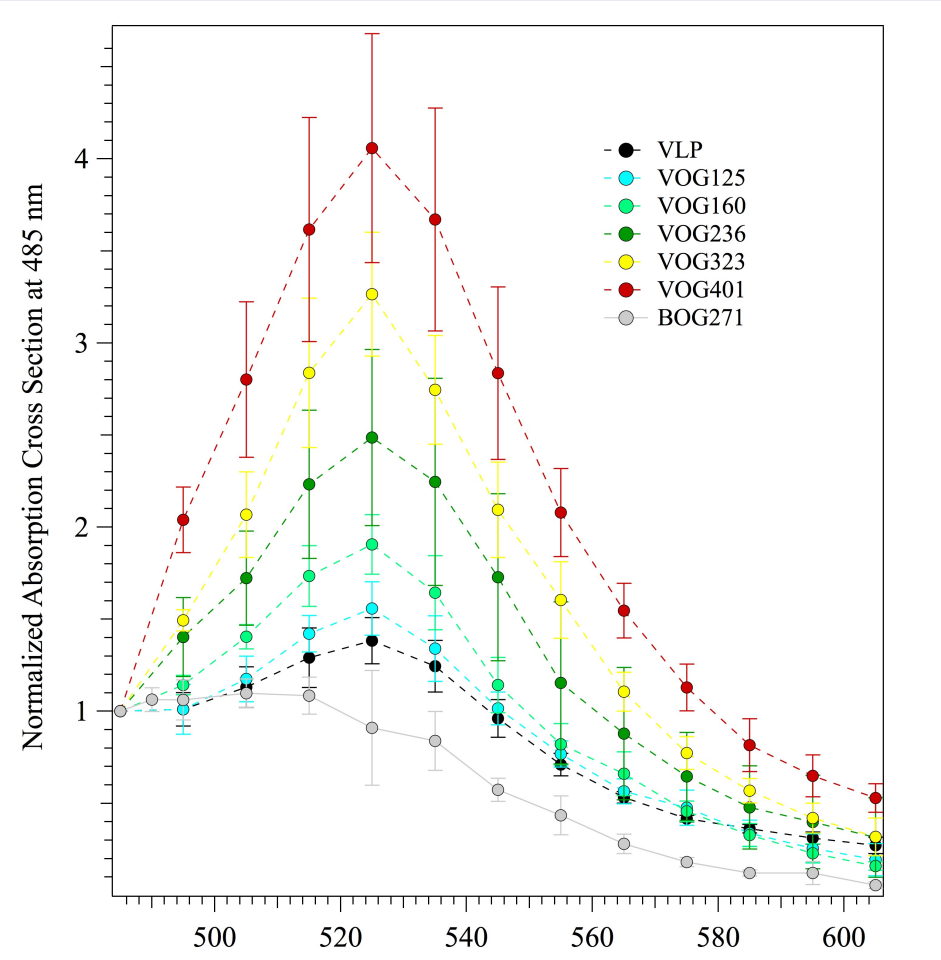
Transient absorption

Transient absorption is modulated at a frequency predicted for virus vibrations.



Enhanced absorption Au-NP-fVLP

Photothermal single-particle spectroscopy. Absorption cross-section is enhanced 4× at plasmon resonance without increase in diameter.



Results Dissemination

Manuscripts:

- "A Subset of Fluorophores is Responsible for Radiation-Brightening in Viromimetic Particles". J. Phys. Chem. (Accepted)
- "Hydrophobic Cargo Encapsulation into Virus Protein Cages by Self-assembly in an Aprotic Organic Solvent", Bioconj. Chem. (Under review)
- "Virus Assembly Pathways Inside a Host Cell", under review at ACS Nano.
- "Ultrafast Excited State Dynamics of a Virus-supported Fluorophore Array Antenna", under internal review.
- "Virus mechanics under molecular crowding". J. Phys. Chem. B, 125, 1790-1798. https://doi.org/10.1021/acs.jpcb.0c10947

Two invited perspectives waiting to be written.