Laser System Optimization and Investigation into Photodissociative Pathways of $Mn_2(CO)_{10}$

Part 2: Laser System Evolution

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Introduction

The Nd:YAG-pumped, doubled dye laser system used in the Carleton College Chemistry Deparment is constantly evolving to fit the needs of current research and requirements of safety, functionality, and efficiency. Improvements to the system in these areas was the primary focus of the 2010 summer session. The system is used primarily to probe the dissociative pathways of organometallic compounds (such as Mn_2CO_{10}), but also aids in a wide array of photochemical explorations including optogalvanic exoeriments and atomic spectroscopy studies. The optimal use of the system requires accurate control over a large range of power. This control, along with proper laser alignment through the equipment is necessary to acquire meaningful, reliable data. Reliability also comes from reproducibility and the removal of the possibility for human error. Most modern labs incorporate computer control of instruments to both facilitate efficient data acquisition and to minimize careless human mistakes. How can we configure this laser system to maximize power output, expand computer control with the Labview program, and establish an

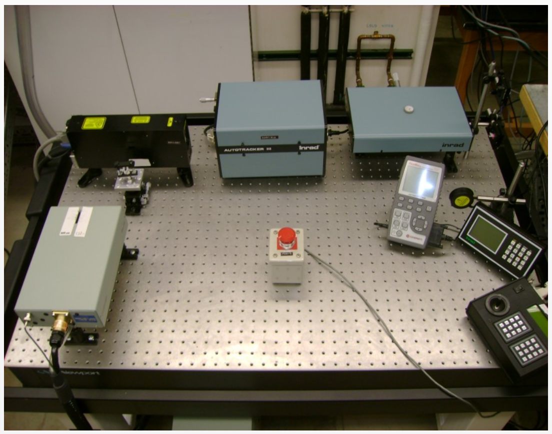


Fig. 1: Current laser array

Building a Stronger Foundation: A New Laser Table and Optimized Alignment

The table on which the laser system sat previous to our work was not ideal for stable and well-aligned experimentation. Its cover was simple sheet metal without a feasible way to lock-down alignment of the whole system. The Carleton College Chemistry Department recently came into possession of several large Isostation™ Vibration Isolated Workstation tables. More important to our needs was the fact that this new table was topped with a stainless steel sheet with screw holes every square inch. This allowed for our instruments to be securely fixed to the table (once aligned), saving hours of re-alignment due to simple bumps or shakes. Once all the instruments were attached, several weeks were consumed in painstakingly aligning each part of our 7 piece array in all three dimensions, making sure the laser beam was perfectly horizontal, did not veer off-axis, and maintained a proper balance between beam shape and overall power output.

Removing the "Oops" Factor: Labview Programming and Computer Control

A dye laser is an incredibly useful tool in photochemical research due to the fact that, unlike many other types of laser, it is not monochromatically confined , but (depending on the dye) can produce light over a wide range of wavelengths. The controller for the dye laser had several problematic features that we gradually became aware of; reported wavelength changed with scan direction and was not reproducible, and we lacked of the ability to perform a continuous scan over the dye range. Using the National Instruments program

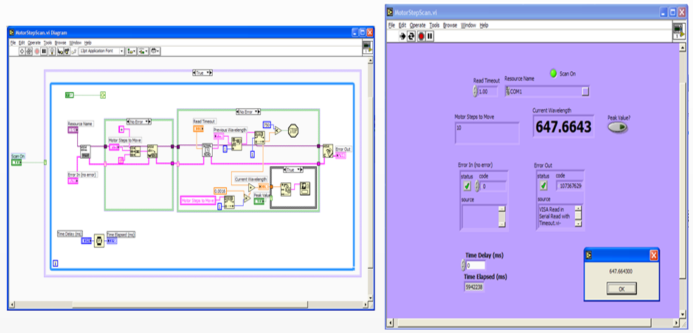


Fig. 2: Front Panel and Block Diagram of dye laser virtual instrument

Labview programs are also used to gather ion fragments—the final result of photodissociative experiments. A specific program was developed for each type of photodissociation experiment:

Type I ("snapshot") - Ions are collected monochromatically and analyzed for peak area and fragment manifestation.

Type II ("real-time video") - Ions are collected as the dye laser scans over a wavelength range and changes in fragment data are analyzed as the wavelength of laser light changes.

(For more detail, see Part I: Experimental Theory and Setup)

A mixture of adapting the old programs and new coding provided us with the ability to monitor a specific ion as opposed to simply the entire m/z range. The new programs also added a much-needed quantitative quality by using calculus techniques to automatically calculate normalized ion intensities with each successive iteration ("frame") in a Type II experiment.

Ad Infinitum: Reproducibility in the Lab

System power fluctuations hampered our ability to accurately determine the meaning of our ion intensity data. Numerous power studies, and the installation of a polarizer allowed us to elucidate the relationship between the changing dye laser power with the ion peak intensity to clearly distinguish subtle changes in peak intensity (resonant states). The same power studies were repeated on the doubled light for a more accurate correlation between intensity and laser power. These curves are shown in Fig. 3.

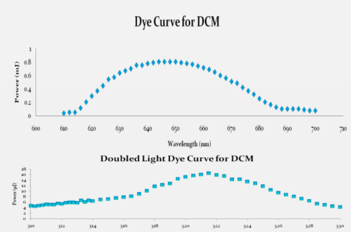
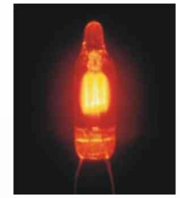


Fig 3. Power studies for DCM dye



Hitting the Wavelength Bullseye: Optogalvanic Calibration

The Northern Lights Dye Laser is essential to our experimental methods, but the true lasing wavelength is needed if meaningful data are to be retrieved. The dye laser was factory calibrated to 588.4895nm, and as the laser deviates from that wavelength, the difference between the "true" wavelength and "given" (by the laser control box) wavelength increases. Assuming a linear offset from the true wavelength, we used neon-

$$\lambda_{true} = .995(\pm.001)\lambda_{dye} + 3.0(\pm.6)$$

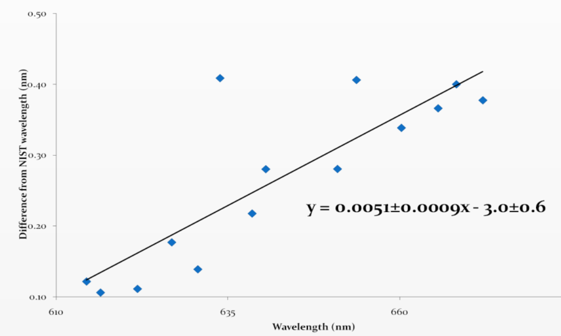


Fig. 4: Calibration of Northern Lights Dye Laser using NIST Ne data

Light in the 600-700nm range is not energetically sufficient for our experimental needs, so the laser light wavelength is halved, doubling the energy (See Part 1). Successful doubling depends on the angle at which the light strikes the doubling crystal and the wavelength of light passing through it. Creating a tuning curve relating the crystal tilt angle and the wavelength for our new, improved alignment reduced time spent searching for the correct angle required for maximum doubled light power.

Conclusions and Future Work

While not the final goal of our research, all the calibrations, improvements, alignments and computer programs are essential to the reproducibility and scientific integrity of the experiments carried out in the lab. Upon completion of these improvements, we were able to acquire and analyze photodissociation data with greater ease and confidence than ever before. There is still room for improvement in the realms of safety, accuracy and computer control. Future projects include installation of a safety box surrounding the system to prevent light scattering and reflections, more complex and useful labview programming including gaining computer control over the wavelength doubler. The majority of modern physical chemistry research is preparation and equipment troubleshooting, and unforeseen problems are always just over the horizon to hinder progress, but eventually be overcome.

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