Development of Frequency Domain Multidimensional Spectroscopy

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CMDS

The Wright Group focuses on the development and usage of Coherent MultiDimensional Spectroscopy (CMDS).

CMDS is a family of related nonlinear spectroscopic experiments.

Why CMDS?

[A BUNCH OF COOL PUBLICATIONS—FOCUSING ON COHERENCE TRANSFER, MECHANISMS ETC] [MORE APPLICATIONS]

Coherence in Energy Transfer and Photosynthesis

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Analytical

But wait! I'm an *Analytical* Chemist...

What am I doing in a field so rich with fundamental studies?

I hope to convince you that CMDS can be used for analytical work.

ACCOUNTS
of chemical research

Mixed Frequency-/Time-Domain Coherent Multidimensional Spectroscopy: Research Tool or Potential Analytical Method?

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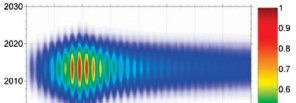
CONSPECTUS

Coherent multidimensional spectroscopy (CMDS) is now the optical analogue of nuclear magnetic resonance (NMR). Just as NMR heteronuclear multiple-quantum coherence (HMQC) methods rely on multiple quantum coherences, achieving widespread application requires that CMDS also excites multiple quantum



ACCOUNTS
of chemical research

Biological and Biomedical Applications of Two-Dimensional Vibrational Spectroscopy: Proteomics, Imaging, and Structural Analysis

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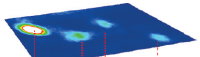
CONSPECTUS



In the last 10 years, several forms of two-dimensional infrared (2DIR) spectroscopy have been developed, such as IR pump−probe spectroscopy and photon-echo techniques. In this Account, we describe a doubly vibrationally

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Generation of Simplified Protein Raman Spectra Using Three-Color Picosecond Coherent Anti-Stokes Raman Spectroscopy

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The well-known and prominent marker bands of aromatic amino acids in Raman spectra of protein and peptide films are revisited in the frequency and time domains using three-color picosecond coherent anti-Stokes Raman spectroscopy (CARS). We show here that control of the probe delay allows the narrow width/long lifetime states to be observed free not only from nonresonant background and fluorescence contamination but also free from the spectral congestion that arises from the complex background of spectrally broader (shorter lifetime) vibrational modes. The reasonable limits of detection obtained indicate that such CARS methods may be useful for quantitative analysis of protein composition.

Introduction

The relative and absolute quantification of proteins and their amino acid composition from separated cell extracts is of central importance in the field of proteomics. The possibility of performing such analyses by optical means, on proteins separated, for example, by capillary electrophoresis (CZE) or

spectroscopy that helped to reduce spectral congestion of the protein spectra was the ability to select only coupled vibrational states (the fundamental feature of multidimensional vibrational spectroscopy). The method also employed picosecond delays between the excitation pulses to reduce the levels of nonresonant background relative to the desired signals.[9]

Domains of CMDS

CMDS can be collected in two domains:

- time domain
- frequency domain

Time domain

Multiple broadband pulses are scanned in *time* to collect a multidimensional interferogram.

A local oscillator must be used to measure the *phase* of the output.

This technique is...

- fast (even single shot)
- robust

pulse shapers have made time-domain CMDS (2DIR) almost routine.

Frequency domain

In the Wright Group, we focus on *frequency* domain "Multi-Resonant" (MR)-CMDS.

Automated Optical Parametric Amplifiers (OPAs) are used to produce relatively narrow-band pulses. Multidimensional spectra are collected "directly" by scanning OPAs against each-other.

This strategy is...

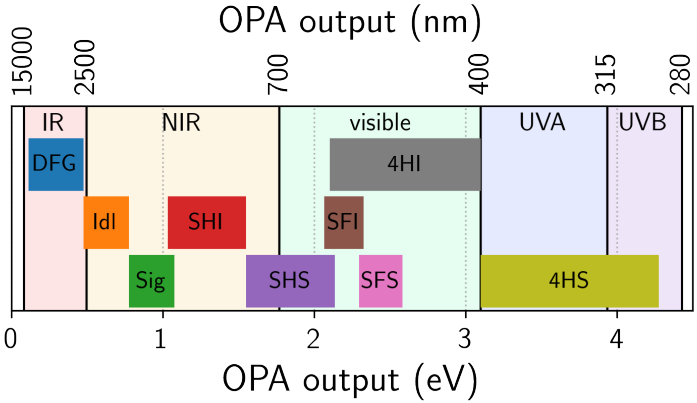
- slow (must directly visit each pixel)
- fragile (many crucial moving pieces)

but! It is incredibly flexible.

Bandwidth

MR-CMDS has no bandwidth limit!

There is just the small matter of making the source continuously tunable...



Selection rules

MR-CMDS can easily collect data without an external local oscillator.

This means... [BOYLE]

The instrument

[PICTURE OF LASER LAB]

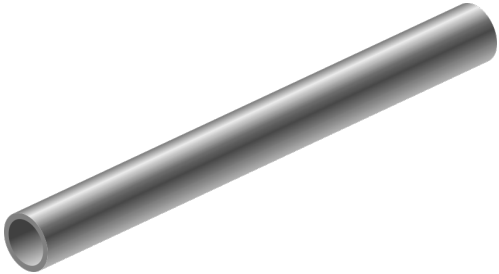
The instrument

Many kinds of component hardware

- monochromators
- delay stages
- filters
- OPAs

$\sim$ 10 settable devices, $\sim$ 25 motors.
Multiple detectors.

Pipeline



What does the “pipeline” of MR-CMDS data acquisition and processing look like in the Wright Group?

How to increase data throughput and quality, while decreasing frustration of experimentalists?

Processing

WrightTools.

Universal format

Flexible data model

Acquisition

PyCMDS.

Modular hardware model

Acquisitions

Queue

This strategy can be incredibly productive!

- Soon after the queue was first implemented, we collected more pixels in two weeks than had been collected over the previous three years.

Tuning

MR-CMDS theory

Mixed domain

[FIGURES FROM DAN'S PAPER]