SFG SPECTROMETER

Picosecond Vibrational Sum Frequency Generation (SFG) Spectrometer

Powerful and versatile tool for *in-situ* investigation of surfaces and interfaces:

- ✔ Sensitive to sub-monolayers
- ✔ Applicable to all interfaces accessible by light
- ✔ Remote sensing in hostile environment
- ✔ Highly surface-specific
- ✔ High spectral and spatial resolution
- ✔ Process dynamics monitoring

FEATURES

- High S/N ratios due to the superb laser source stability
- Wide measurement range: 4300 – 625 cm^{-1}
- Better than 6 cm^{-1} spectral resolution
- Cost-effective picosecond system approach
- Complete PC controlled system
- Azimuth scan, XY-mapping, surface dynamics investigation
- Double resonance option

APPLICATIONS

- Molecular characterization of polymers, polymer blend surfaces, and buried interfaces
- Investigation of liquid interfaces
- Study of molecular structure of monolayers
- Determination of orientation of terminal groups and absolute polar orientation of surface atomic groups
- Investigation of organic molecules at solid/liquid interfaces in electrochemical cells
- Study of surface reactions under real atmosphere and catalysis
- Your application is welcome...

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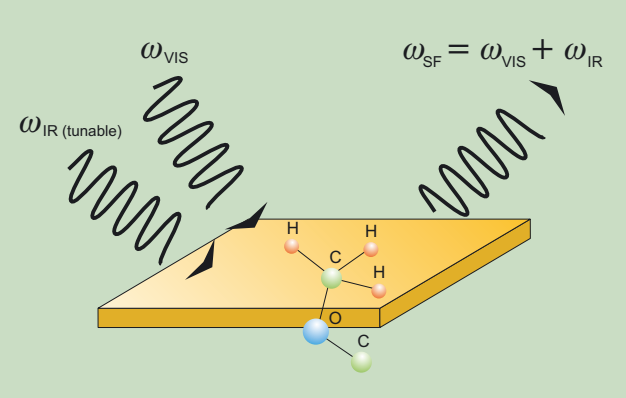
BASIC OPERATION PRINCIPLES

Sum Frequency Generation (SFG) is a second-order nonlinear optical process, which is used to generate **a vibrational spectrum of molecules at an interface**.



SFG, a **three-wave mixing process**, is generated trough overlapping of infrared (ω_{VIR}) and visible (ω_{VIS}) laser beams to produce an output at the sum frequency ($\omega_{SFG} = \omega_{VIR} + \omega_{VIS}$). Active vibrational modes of molecules at the interface give a resonant contribution to SFG signal, thus allowing **identification of the molecules** located at the interface.

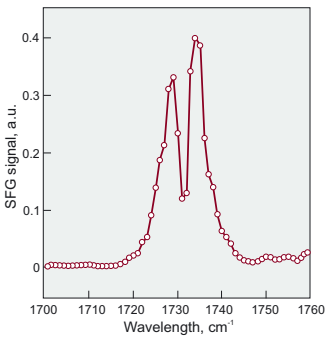
Different polarization combinations of both VIS and IR pump beams and analysis of the SFG signal polarization provides important information about **orientation of vibrational modes** adsorbate.

Since SFG detects vibrational modes, which are rather localized to specific groups of atoms within the molecules, information about **relative orientation of different groups** within the same molecule might be obtained, and, hence, the molecular formation might be deducted.

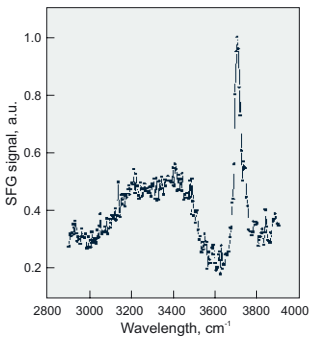
Referring to the SFG signal phase measurements, information about the **absolute orientation of molecule** in respect to the surface might be obtained.

There is no contribution to SFG signal from bulk material since the SFG signal is generated directly in the interface.

EXAMPLES OF SFG SPECTRA



SFG spectrum of monoolein
1 cm^{-1} scan step, 200 acquisitions per step.
Courtesy of EKSPLA Ltd.



Water-air spectrum
200 acquisitions per step.
Courtesy of University of Michigan

PARTS OF THE SFG SPECTROMETER

SFG SPECTROMETER INCLUDES:

- Picosecond Nd:YAG laser
- Harmonics generation unit
- Optical parametric generator / amplifier / difference frequency generator (OPG/OPA/DFG)
- Monochromator
- Signal detectors
- Data acquisition system
- Controlling software
- Beam delivery optics
- Guiding beam for system alignment

OPTIONAL ACCESSORIES:

- Sample compartment including six axis sample holder
- Microstepping motor controller
- Reference channel

Sum frequency excitation system is based on picosecond pump laser and optical parametric generator/amplifier/difference frequency generator (OPG/OPA/DFG).

Mode-locked Nd:YAG laser with solid-state saturable absorber and active negative feedback delivers picosecond pulses with extra-stable energy and pulse duration.

Second harmonic of laser fundamental radiation (532 nm) is used as the VIS beam for SF generation and to pump **OPG/OPA**. Mid-IR radiation is generated by mixing OPG/OPA idler beam with laser fundamental radiation (1064 nm) in **difference frequency generator**. Spectral and spatial filtration of OPA seed beam ensures narrow spectrum and low divergency of mid-IR radiation. Beam walk-out compensation design excludes beam-pointing instabilities during wavelength scan.

VIS beam delivery optics includes: spatial filter for ensuring homogenous 532 nm beam spatial profile, energy and polarization control system for smooth adjustment of pulse energy and polarization direction, delay line for temporal overlap of VIS and IR pulses.

IR beam polarization is controlled by set of mirrors. The energy of the both **VIS and IR beams** are monitored for SFG signal normalization by the photodetectors.

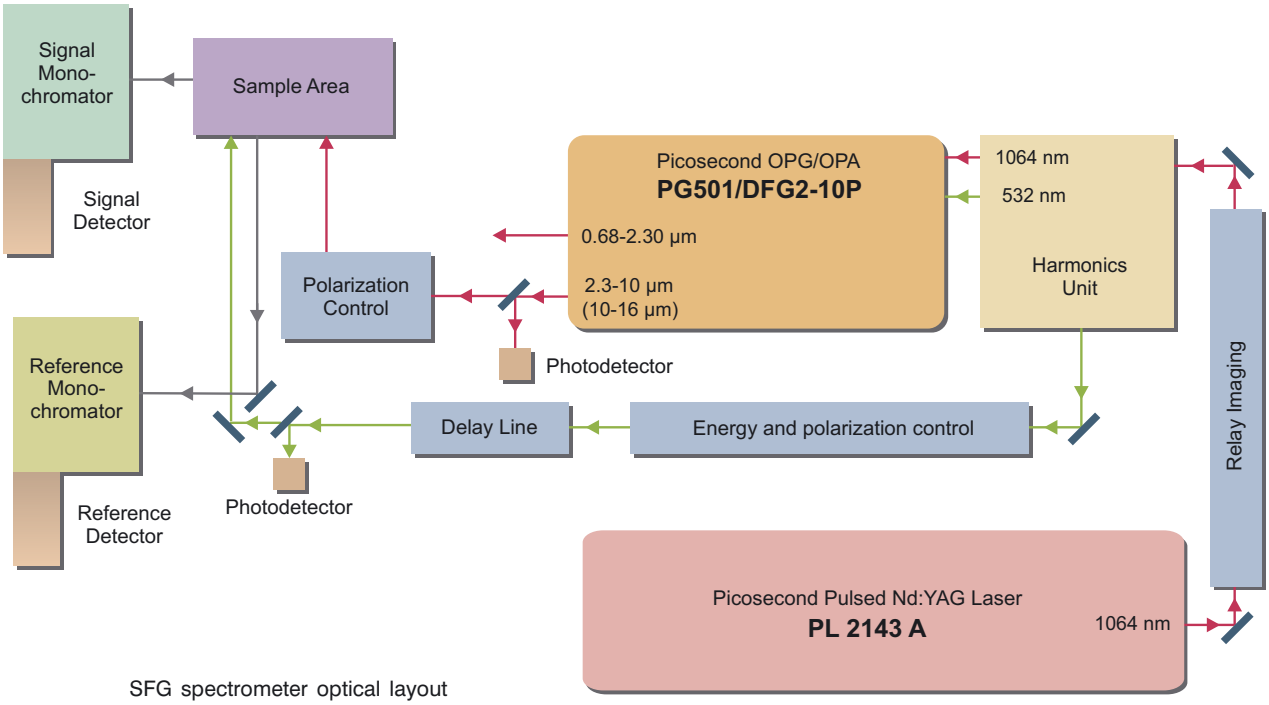
Sample compartment including six axis (three translation and three rotational, including PC controlled Y, X and q axes) translation/rotation stage is used for quick and precise sample positioning. The rotation stage enables investigations of SFG signal dependence on sample orientation. Translation stages allows sample mapping.

SF channel includes steering mirrors, collecting lens, polarization analyser and holographic notch filter for scattered VIS light rejection.

Detection system consists of monochromator and gated PMT based SF signal detector.

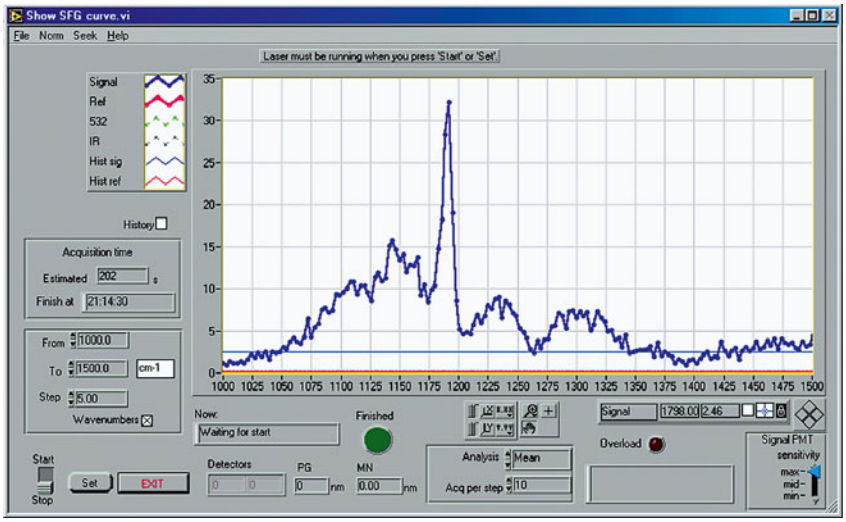
Low power laser diode **guiding beam** makes system alignment easier.

Optional **reference channel** improves the sensitivity of spectrometer and enables to reduce data acquisition time.



SFG spectrometer optical layout

SOFTWARE



All the spectrometer units (laser, optical parametric generator / amplifier / difference frequency generator (OPG/OPA/DFG), monochromators, photodetectors) are controlled from **computer** using **LabVIEW™** drivers. Spectrometer software includes options of SFG spectra acquisition, azimuth scan, XY-mapping, surface dynamics investigation, OPG/OPA/DFG calibration.

SPECIFICATIONS

GENERAL	
Operation wavelength	2.3 – 10 μm (4300 – 1000 cm^{-1}) [1]
Spectral resolution, cm^{-1}	< 6
Data acquisition rate, Hz	10
VIS BEAM	
Wavelength, nm	532 [2]
Linewidth, cm^{-1}	< 2
Pulse energy (at 532 nm), mJ	~ 1 [2]
Pulse duration, ps	20 – 30
Polarization	Linear; selectable s or p; purity >1:100
IR BEAM	
Wavelength, μm	2.3 – 10 [1]
Linewidth, cm^{-1}	< 6
Pulse energy, μJ	
2.3 μm	> 200
4 μm	> 260
6 μm	> 200
8 μm	> 100
10 μm	> 40 (>100 optional)
12 μm	> 75 (optional)
14 μm	> 45
16 μm	> 40 (optional)
Polarization	Linear; selectable s or p; purity 1:100
SFG BEAM	
Wavelength	432 – 517 nm (λ_{VIS} = 532 nm) 728 – 1005 nm (λ_{VIS} = 1064 nm)

[1] *Optional 16 μm (625 cm^{-1}) upgrade is available.*
[2] *Optional 1064 nm upgrade is available.*

Specifications are subject to changes without advance notice.

BUILDING OR UPGRADING YOUR OWN SFG SYSTEM?

Take advantage of our more than 12 years experience. EKSPLA offers:

- Highly qualified consultations and assistance
- Picosecond Nd:YAG lasers with outstanding stability
- Picosecond OPO/OPG/DFG
- Laser accessories and components
- Photonics components, beam delivery optics

SFG SPECTROMETER OPTIONS AND RELATED PRODUCTS

DOUBLE RESONANCE

For investigation of coupling of vibrational modes with electrons at a surface double resonance SFG spectrometer is available. Double resonance is achieved by adding second OPG/OPA as tunable VIS beam.

SPECTRAL RESOLUTION DOWN TO 2 cm^{-1}

Using narrowband OPO/OPA/DFG with synchronously pumped parametric oscillator decreases SFG spectral resolution down to 2 cm^{-1}

1064 nm VIS BEAM IN ADDITION TO STANDARD VIS (532 nm)

Metals, like gold, silver and etc. have a low laser damage threshold at 532 nm and significant absorption of the 532 nm radiation. Therefore, for SFG spectroscopy of metal interfaces 1064 nm beam as VIS is offered due to higher laser damage treshold and lower absorption of 1064 nm radiation.

SECOND HARMONIC GENERATION (SHG)

Second harmonic generation (SHG) is other effective tool for surface probing. The monolayer adsorbtion could be detected by SHG. With different input/output beam polarizations SHG could yield information on the average orientation of molecular adsorbates. The surface symmetry measurements could be performed by rotation of the sample around the surface normal. By using tunable lasers, SHG can yield surface-specific monolayer spectroscopy.

SHG spectrometer is available as accessory to the SFG spectrometer or stand-alone system.

Requests for custom made products are welcome !

EKSPLA
An EKSMA Group Company

Lasers and Laser Systems Div.
Savanoriu av. 231
02300 Vilnius – 53
L I T H U A N I A

Ph.: +370 5 2649629
Fax: +370 5 2641809
sales@ekspla.com
www.ekspla.com

EKSPLA distributor in United Kingdom:

Laser Systems Ltd.
INGCRYS

Ingcrys Laser Systems Ltd
14 Parrs Road, Stokenchurch,
High Wycombe, Bucks. UK
Tel.: + 44 (0) 1494 482541
Fax: + 44 (0) 1494 482873
Email: sales@ingcrys.com
www.ingcrys.com

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