# *Vibrational Sum-Frequency Scattering Spectroscopy:*
# A tool for studying the chemical properties of nanoparticle surfaces

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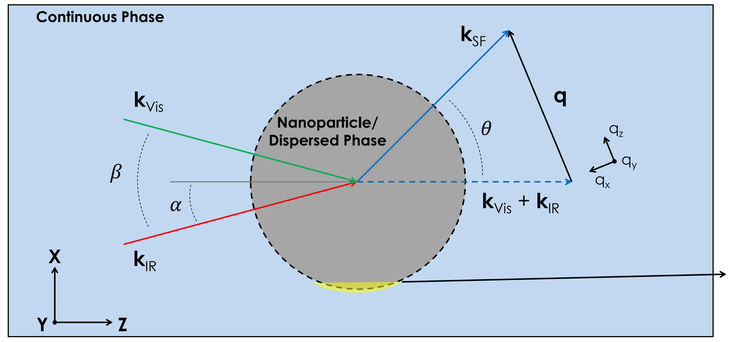
## Introduction to Vibrational Sum-Frequency Scattering Spectroscopy

Vibrational sum-frequency scattering (SFS) spectroscopy is a nonlinear spectroscopic method that measures the vibrational spectrum of molecules adsorbed to nanoparticle surfaces within a colloidal suspension. Similar to sum-frequency experiments of extended planar interfaces, SFS spectra can provide insight into molecular conformation, orientation, chemical bonding, and more, of molecules at nanoparticle surfaces. Since the first SFS experiments in 2003, this method has been applied to study the physicochemical properties of emulsion, aerosol, nanoparticle, and nanoplastic surfaces.

## Connecting the Laboratory to the Nanoparticle Surface




$$I_{SFS} = \left|\Gamma^{(2)}\right|^2 I_{Vis} I_{IR}$$

$$\Gamma^{(2)} \rightarrow \chi^{(2)} \rightarrow \beta^{(2)}$$

Particle ⟶ Molecular

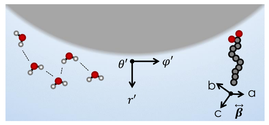
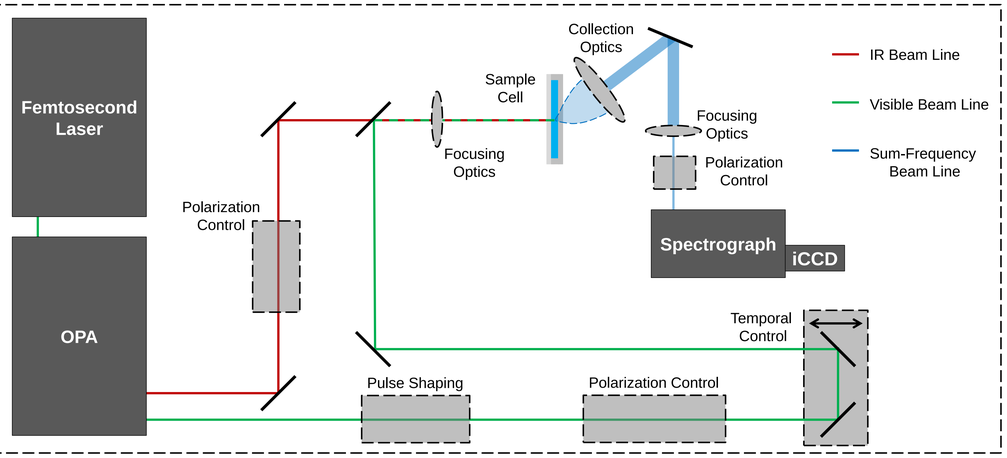


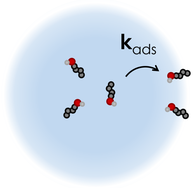

Image adapted from Carpenter, A.P. *Molecular Structure and Bonding at Nanoemulsion surfaces* (2020)

## General Experimental Design




## SFS studies of Aerosols, Emulsions, Material Systems, and Beyond

Adsorption dynamics of **aerosol** surfaces.



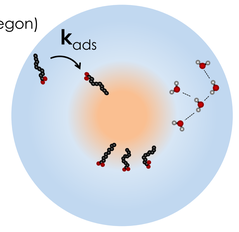

***Some Relevant Groups:***
Rao Group (Utah St. University)
Roke Group (EPFL)
Weidner Group (Aarhus University)

***Some Relevant Publications:***
10.1038/S42044-022-00674-8
10.1021/acs.jpca.2c03346
10.1038/s42004-023-00903-8
10.1038/s42004-023-00904-7

Adsorption, molecular structure and bonding at **nanoemulsion** surfaces.

***Some Relevant Groups:***
Roke Group (EPFL)
Richmond Group (University of Oregon)

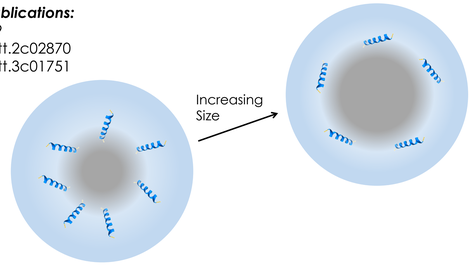
***Some Relevant Publications:***
10.1021/ja9095158
10.1021/jp200536k
10.1073/pnas.1700099114
10.1073/pnas.1900802116
10.1038/ncomms15548
10.1021/acsnano.7b05100



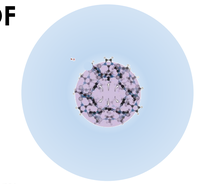

Protein structure at **nanoparticle** surfaces.

***Some Relevant Groups:***
Weidner Group (Aarhus University)

***Some Relevant Publications:***
10.1116/6.0000419
10.1021/acs.jpclett.2c02870
10.1021/acs.jpclett.3c01751




Structure of solvation shells at **colloidal MOF** surfaces.



***Some Relevant Groups:***
Richmond/Scatena/Brozek Groups (University of Oregon)

***Some Relevant Publications:***
10.1021/acsnano.4c03758

MOF image adapted from:
Mapile, A. et. al *ACS Nano* **2024** 18, 20, 13406-13414

## Key Components for Implementing SFS in the Laboratory

**Excitation Resources**
- Femtosecond Laser Source (800 or 1064 nm)
- OPA for broadband IR pulse generation. (2500 – 10000 nm

**Optics**
- Polarization Control (ex. λ/2-wave plate)
- Pulse Shaping Mechanism (ex. 4f, SHBC, etalon)
- Reflective/Focusing Optics

**Detection Resources**
- Intensified CCD (ex. iStar 334)
- Spectrograph (ex. Kymera 328i)

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