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OUTLINE

• MOEMS Technology for Micro Mirror Spectrometers

• Prototype Development of Micro Mirror Spectrometer Devices

• Applications of Micro Mirror Spectrometers

• Creation of Ultra intense Light Filaments for Environmental Sensing using a High Power Ultra Fast Laser System

• Applications of the ??? System
Current Devices for Spectroscopy

**NIR Array spectrometer**
- Wavelength selection of radiation by dispersive elements
- Acquisition of the radiation by a detector array

**MIR/FIR FTIR-Spectrometer**
- Acquisition of the whole spectrum via an interferogram
- Separation of the particular radiation wavelength by means of Fourier-transformation

Limited analyzable spectral range

High costs and limited mobility
Functional Principle of the Micro Mirror Spectrometer

**Entrance Slit**
- Produces a well defined source region of the radiation emitter

**Parabolic Reflector**
- Makes the incident light parallel and focuses the diffracted light back to the detector slit

**Micromirror**
- Scans the first order diffracted light over the detector slit

**Diffraction grating**
- Produces the spectral dispersion of the radiation

**Detector slit**
- Determines the wavelength / wavenumber resolution
Specific Requirements for Spectrometer use:

- Low resonance scan frequency (250...275 Hz)
- High deflection angle (+/- 6,5°) for realization of a wide spectral range
- Large mirror surface area (6x9 mm²) for high radiation throughput
- High reflective coating (CrAu) for the IR radiation
Signal Flow of the Micro Spectrometer Device

Driving Signal

DAC

Mirror-drive
Tilt-Detector

MC68332
ADC 3
ADC 2
ADC 1

First Harmonic Response

Time

Angle

Wavelength

Sensing Results:
Probe Identification and Concentration

Database

Microcontroller
MPC 823
Ultra Compact Hybrid Setup of a Micro Mirror Spectrometer

Low Adjustment Tolerances and High Vibration Stability
Micro Mirror with Integrated Diffraction Grating

- Simplified optical design
- Increased integration of optical components ⇒ reduced alignment errors
- Smaller size and weight

APW Inc. U.S Patent pending
Spectral Calibration of the Micro Mirror Spectrometer

Spectrometer Parameters

- Measurement Range: 2 - 5 µm
- Spectral Resolution: ≥ 40 nm
- Signal to Noise Ratio: 335:1
  (Measurement Period: 1 s)
Spectrometer Based on MOEMS are a Promising Alternative to Conventional Spectroscopic Devices

- more compact, cost effective and usable outside the laboratory

Performance Characteristics of the Presented Spectrometer

- Spectral range of 2 - 5 µm
- Spectral resolution of 40 nm …

Prospects

Extension and Variation of the Spectral Range

Improvement of the Spectral Resolution
IMPORTANT APPLICATIONS FOR MICRO MIRROR SPECTROMETERS

- Micro- & Nanotechnology
- Environmental Sensing
- Femtosecond LIDAR Systems
- Biophotonics
- Biomedical and Bioengineering
- Biotechnology
- Imaging at Cellular, Molecular level
- Multiple Imaging Modalities
- In vivo Skin, Hair and Tissue Diagnostics
- Industrial Health Safety
- Drug and Gene Delivery Systems
- Homeland Security & Defense
Mobile Terawatt Femtosecond LIDAR System (MTFLS) for Long Range Detection of Biological, Chemical and Nuclear Agents

Experimental set-up of the supercontinuum LIDAR system. (Wille et al. 2002)
Broadband “white light” continuum generation (230nm - 4µm). This white-light source covers the absorption bands of many atmospheric pollutants (Multi-Component Optical Remote Sensing).

- Critical threshold power $P_{c}$ (~ 3GW) for formation of filaments that can propagate in quasisolitonic way through the air.

- These narrow and long waveguide like structures result from a balance between Kerr self-focusing and self-defocusing by multiphoton ionization of air molecules.

- The high light intensity (~ $10^{14}$ W/cm$^2$) and electron density inside the filament modify the medium properties while propagating.
Measured spectrum of the white light super-continuum generated by 2-TW femtosecond Laser pulses. (Kasparian 2002)
Long-distance white-light propagation and control of nonlinear optical processes in the atmospheres. Images of the Teramobile fs laser beam propagating vertically were taken with the charge-coupled device camera at TLS observatory. (A) Fundamental wavelength, exhibiting signals from more than 20 km and multiple-scattering halos on haze layers at 4- and 9-km altitudes. (B to D) White light (385 to 485 nm) emitted by the fs laser beam. These images have the same altitude range, and their common color scale is normalized to allow direct comparison with that of (A). (B) With GVD precompensation. (C) Without GVD precompensation. (D) With slight GVD precompensation. The conical emission imaged on a haze layer is apparent.
Anthrax Spores

Typical Spore Composition:
1. Proteins (15%)
2. RNA (6%)
3. Polysaccharides (3%)
4. Lipids (2%)
5. DNA (1%)
6. Inorganic Ions (1%)
7. Ca-DPA (up to 17%) Ca-DPA: Calcium Dipicolinate

Sketch of a Bacterial Spore with the Listing of the Major Constituents such as Proteins.

Photomicrograph of Bacillus Anthracis Spores
Different Excitation and De-excitation Channels in UV and IR Including Scattering Processes using Femtosecond Lasers

UV Excitation of Bioaerosols and Fluorescence and IR Emission Channels

Absorption 266.7nm

Internal Conversion

Fluorescence

IR Emission Vibrational Features

UV Channel Fluorescence ~ 350nm

fs-TW Laser

800nm

Two-colored Filament

800nm / 266.7nm

IR Channel ~ 3-4 μm

Scattering Channels
Creation of a Nano Plasma in a Water Droplet using a Femtosecond Laser Pulse

Application: Detection of radioactive isotopes like Cesium (CsCl) in the Yucca Mountain Repository.

Ref.: Borrmann and Curtius 2002
Chemical Composition Information based on the White Light Nano-plasma Emission from Contaminated Water Droplet

(a) White light spectrum from pure water droplet.

(b) Na doublet D1-D2 line in emission arising of a water droplet containing NaCl superimposed on a white light continuum.

For atmospheric nuclear agent detection like cesium isotopes, this method could be applied.
Bacillus subtilis extinction aerosol spectrum in the MIR and far IR region (Bruch et al. 2002)

\[ \sigma = 3.9 \times 10^{-7} / \lambda^{2.95} \text{(Mie scattering background)} \]
Multi Spectral LIDAR in the Infrared using a Terawatt Femtosecond Laser System

Bacillus Subtilis absorption aerosol spectrum in the MIR region. (Bruch et. al. 2002).

Sensitivity between 5 – 10 spores/cm³
Schematic of an experimental setup for bio-aerosol detection in the vicinity of a filament plasma channel

APW Inc. U.S & German Patent pending
Pictures of an existing Mobile Teramobile Femtosecond LIDAR system for atmospheric sensing applications.
Uniqueness of Ultraintense Light Filaments generated in the Atmosphere

- A sophisticated differential absorption, fluorescence, Raman, Raleigh and Mie scattering, multi-channel, multi-wavelength, multi-spectral LIDAR system for ground based and air based monitoring of bio-aerosols and chemical agents in real time with high accuracy and reduced false alarms.

- A mobile femtosecond terawatt LIDAR system from a few meters up to 20km range with high temporal and spatial resolution and spectroscopic identification of airborne biological and chemical agents.

- Transmission of laser beams through fog and clouds for free space communication.
Collaborators for the Mobile Terawatt Femtosecond Laser System

- Atmospheric Sciences Division of the Desert Research Institute, Reno, NV
- Applied Photonics Worldwide Inc., Reno, NV
- CrystaLaser LLC, Reno, NV
- University of New Mexico, Albuquerque
- University of Texas at Austin
- Clean Earth Technologies LLC, St Louis, MO
- University of Jena, Germany