LAMMA 2000: a new scanning UV-Laser microprobe for ion imaging and confocal microscopy

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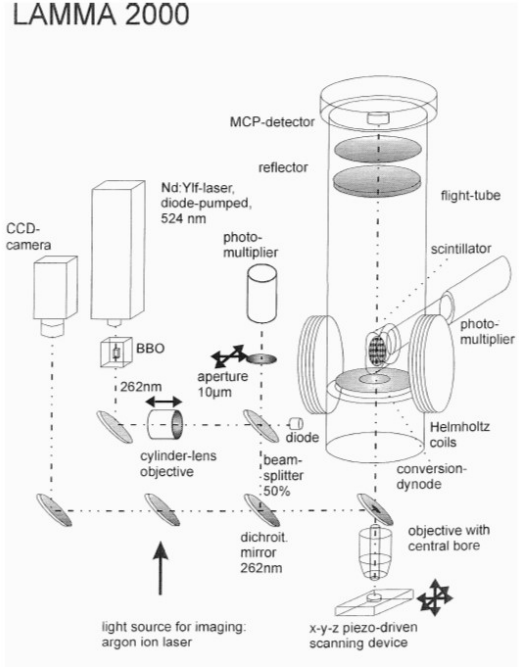
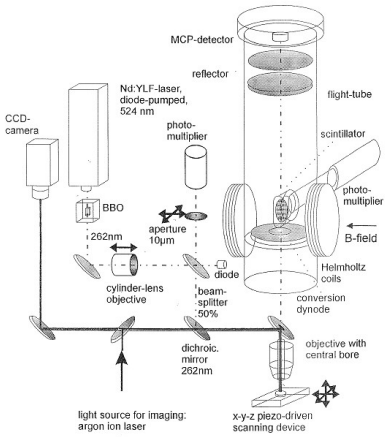
The technical design of a new reflectron time-of-flight laser microprobe mass spectrometer (LAMMA 2000) is presented. Instrumental features are fast ion imaging and optical sample imaging with lateral resolution of 0.5 micrometers. Sample illumination, sample observation, laser irradiation, confocal sample imaging and ion extraction are all performed coaxially through a high-numerical UV-transmitting 5-lens objective equipped with a central bore. A diode-pumped Nd:YLF laser has been frequency-quadrupled to 262 nm and is used for both, laser desorption ionization and sample illumination for confocal scanning microscopy. Advantages of this type of laser are its small physical dimensions and the opportunity to run at high repetition rates of up to 10 kHz, which is a prerequisite for fast imaging.

Sample positioning is performed by a stepper motor driven x-y-z stage. Scanning of an area of 100 x 100 um is done by a high-speed x-y-z piezo stage. For UV confocal scanning microscopy the same quadrupled Nd:YLF laser is used, running at low pulse energy and high repetition rate. As a result of this optical design scanned areas in the optical confocal imaging mode and in the ion imaging mode are exactly identical, allowing high resolution optical control of mass spectral data acquisition.

Data aquisition for optical and ion imaging as well as instrument control is software driven by a Windows-based software package. Acquired mass spectra of each sample pixel are either stored individually or are processed directly to form a set of two-dimensional ion images. A transient recorder board for PC allows an aquisition rate of more than 50 spectra per second. In the optical imaging mode x-y-position and photomultiplier signal are acquired by a high-speed 12-bit A/D converter to build up a confocal image of 400 x 400 pixels within 20 seconds. In addition to that an on-line video camera image is displayed on the PC screen using a PC overlay board combined with frame grabbing functionality to save on-line pictures to hard disk.



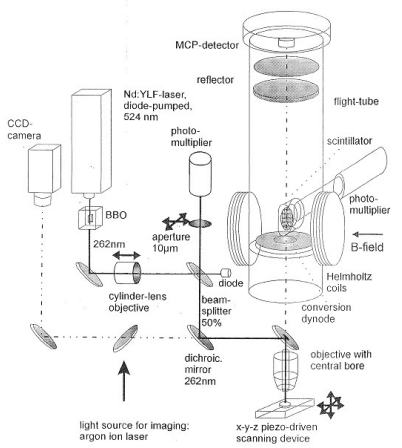
LAMMA 2000: sample observation



For classical microscopical observation the sample is illuminated through the objective lens by an argon ion laser.
An area of 300 x 300 µm is imaged by a video camera. The image of the camera is displayed on a computer screen via overlay board.
It can be stored to hard disk of the computer using a frame grabber card.

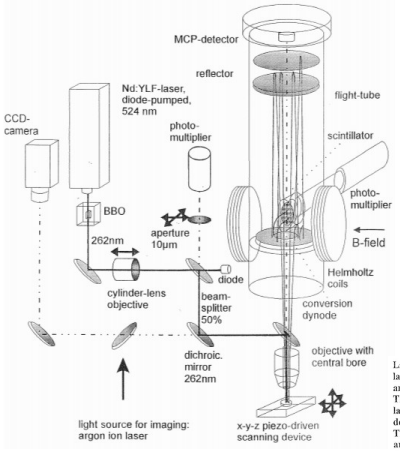
The microscopical imaging supplies online observation of the sample and allows rough positioning with the stepping motor driven sample holder

LAMMA 2000: confocal sample imaging

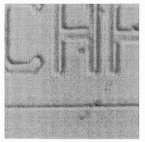


Confocal laser scanning microscopy in the UV can be performed using the same frequency quadrupled Nd:YLF laser at reduced pulse power and a repetition rate of 7000 Hz.
Thus exactly the same area as for the laser desorption ionization mode is scanned.
To our best knowledge this is the first report of using a pulsed UV laser for confocal scanning microscopy.
A complete optical confocal image of 400 x 400 pixels is aquired within 20seconds.
Lateral resolution in the optical confocal imaging mode is about 0.5 µm.

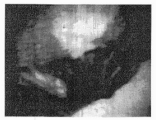
LAMMA 2000: ion extraction



Sample Imaging



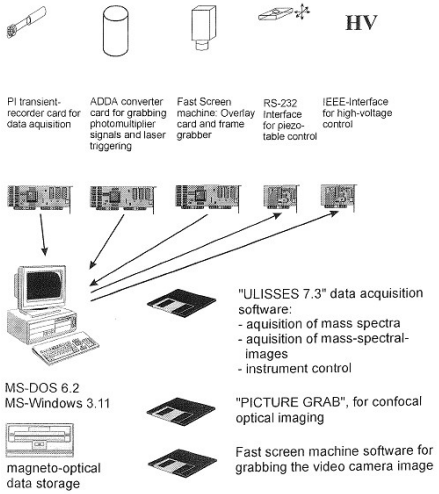
Sample imaging by confocal scanning microscopy. This sample is part of a chip microstructure. Minimal resolution is 0.25 µm. Size of the image is 100 x 100 µm.



This image has been grabbed by the screen machine frame grabber card using a video camera for online observation of the sample. A part of tooth surface is to be seen.

Laser desorption ionization is done using a diode laser pumped Nd:YLF laser (frequency quadrupled, 262nm) of very small physical dimensions and high repetition rates (up to 10 kHz with reduced pulse power).
This is the first report of using a quadrupled diode-pumped Nd:YLF laser for desorption ionization experiments. Lateral resolution in the ion desorption mode is in the range of 0.5 to 1 µm.
The sample is positioned by a stepper motor driven x-y-z stage and an area of 100 x 100 µm is scanned by a highspeed x-y-z piezo stage.
Acquired mass spectra of each sample pixel are either stored individually or are processed to form a set of two-dimensional ion images.
The ion beam is accelerated by gridless ion optics and is lead through the 5 lens objective by a aluminium tube. After passing the 2 stage reflectron the ions are accelerated on a conversion dynode. The resulting electron beam passes through a magnetical field onto the scintillator.

Data aquisition and instrument control



A diode-pumped Nd:YLF-Laser for
1. laser desorption ionization
2. sample irradiation for confocal scanning microscopy

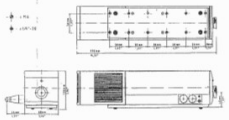
The diode-pumped Nd:YLF laser type ADLAS 421 QD, wavelength 523nm, has been frequency quadrupled to 262nm in our lab.

Advantages of the diode pumped laser:

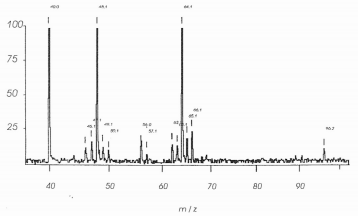
- very small physical dimensions (see figure)
- highly tunable repetition rate from 1 to 10000 Hz, supporting:
  - laser desorption ionization (ca. 50Hz)
  - confocal microscopy imaging (about 7 kHz).
- high pulse to pulse stability
- high electrical efficiency (normal 220/110 V plug)
- no water-cooling necessary
- TTL triggerable

Technical data:

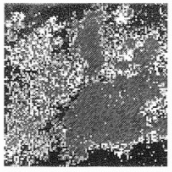
wavelength:	262 nm
pulse energy:	20 microJ
pulse length:	15 nsec
repetition rate:	1 to 10000 Hz
polarization:	100:1
beam divergence:	< 1.8 (mrad) (I/e²)



Data Acquisition: Processing Mass-Spectra to Mass-Mapping



classical mass-spectrum of LAMMA 2000. Data acquisition is done by ULISSES 7.3.



peak intensity of a special element (Fe), together with the coordinates of the positions is processed to a grayscale-image (here: tooth-surface)

Hubert, M. Spengler, B und Kaufmann, R. In Proceedings of the 42nd ASMS Conference on Mass Spectrometry and Allied Topics, Chicago, Illinois, **1994**