Lasers in Space - more than just pew pew!

Anja Kohfeldt

December 27, 2013

30C3, Hamburg

who am I

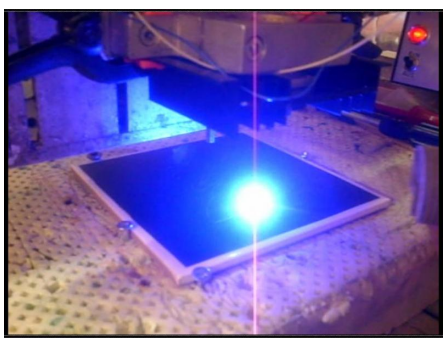
- scientist at Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik in Berlin

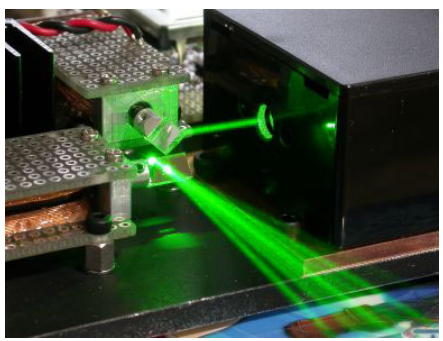
- working in QUANTUS-Project
- building semiconductor based laser modules for MAIUS-Mission (sounding rocket, scheduled Nov. 2014)

motivation

lasers are cool.
alot DIY projects in previous years

- laser cutter
- laser projectors
- pimped laser pointers etc.



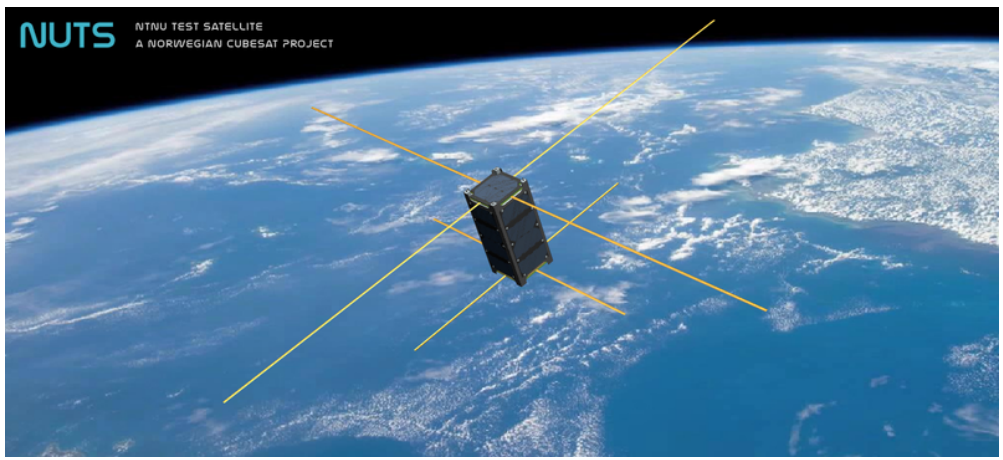


picture sources: reprap, eeweb.com, vilos.com

motivation (2)

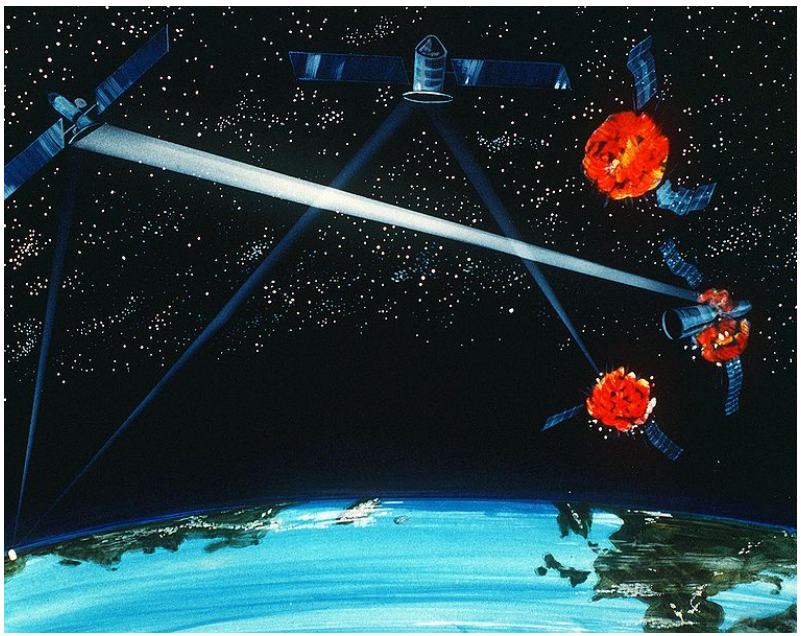
space becomes affordable.

- increase of private activity in space sector
- student & university programs
- μ-Satellites available (e.g. cubeSats as piggyback payload of commercial satellites)

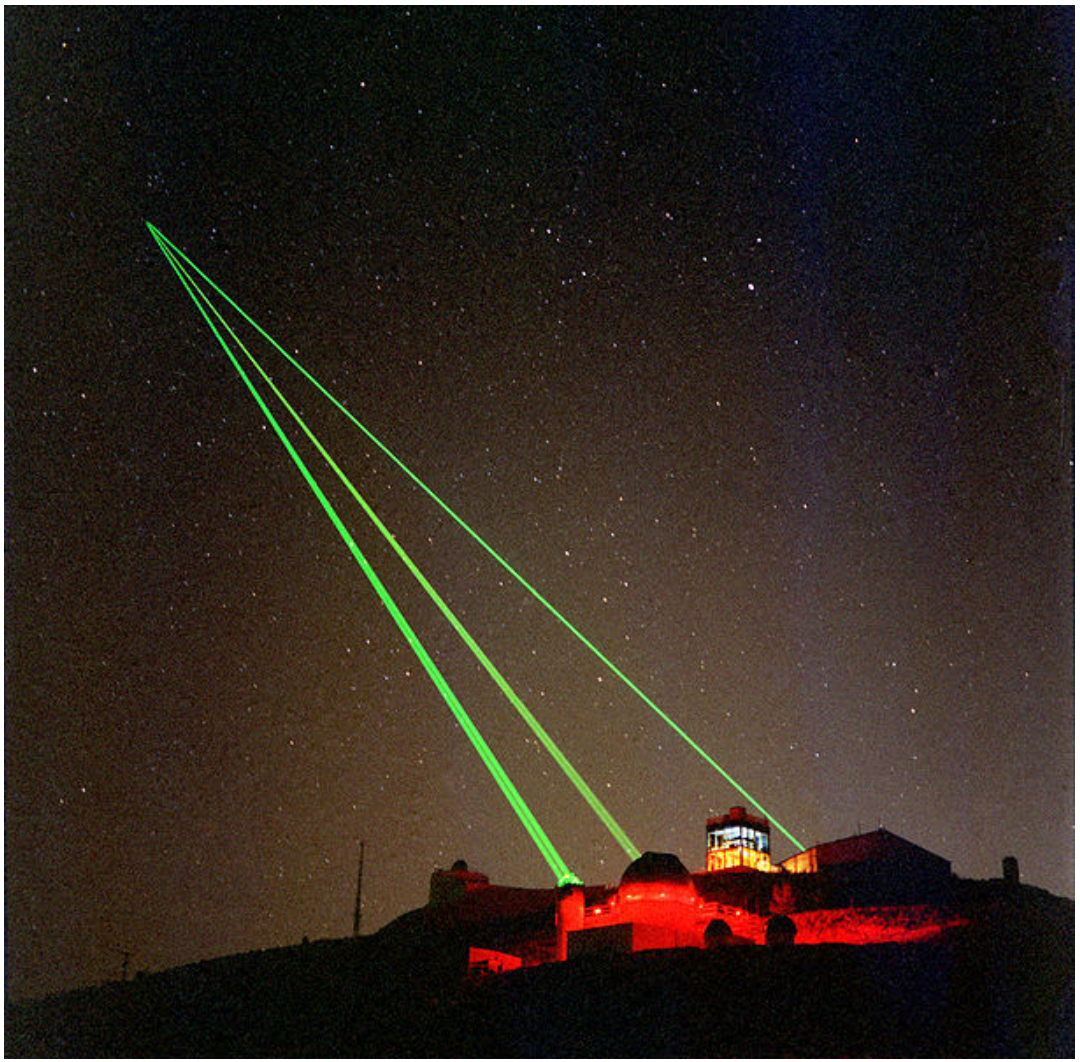


personal motivation

not every laser in space is an orbital death weapon!



nice, but not my topice: lasers into space



Outline

- lasers 101
  - main properties and functionality
  - types and application
- what is "space"?
  - definitions and fields of interest
  - requirements and implementation of space hardware
- applications of lasers in space
  - metrology
  - communication

Outline

lasers 101 (1)

LASER: "light amplification by stimulated emission of radiation"
A device that emits

- monochromatic (1) &
- coherent (2)

photons.

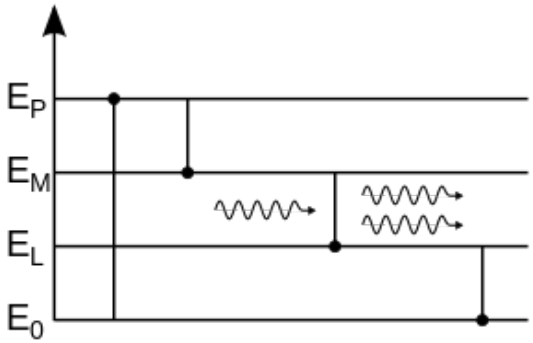
(1)

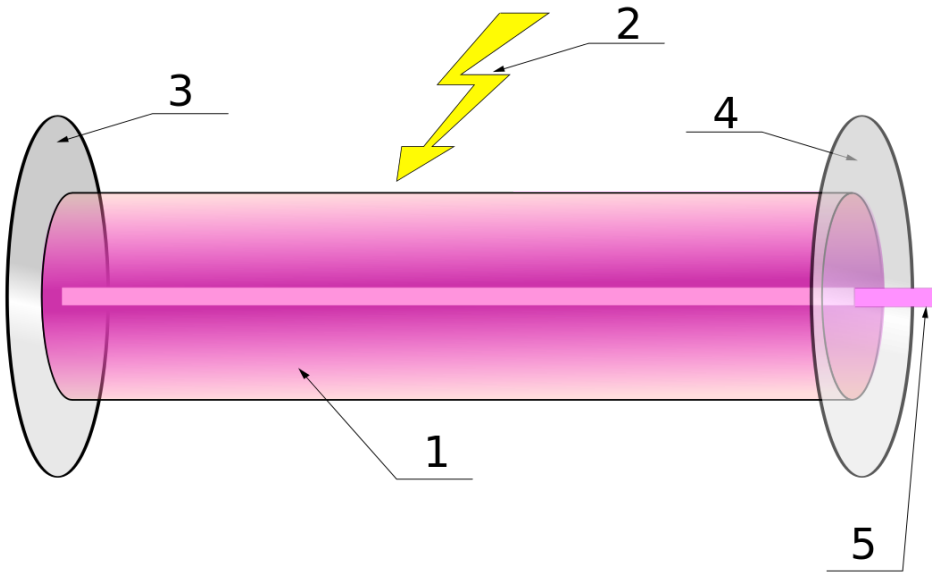
(2)

lasers 101 (2)

required components for laser beam (5):

- active medium (1)
- pump (2)
- resonator (3) & (4)

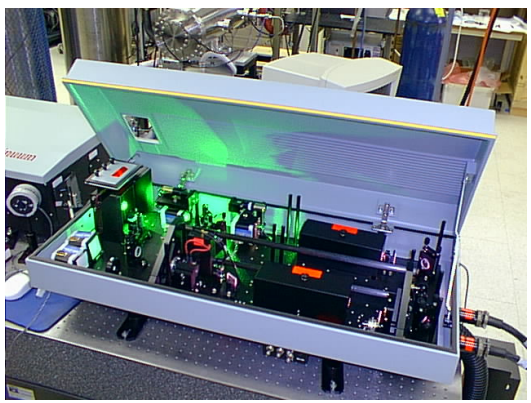


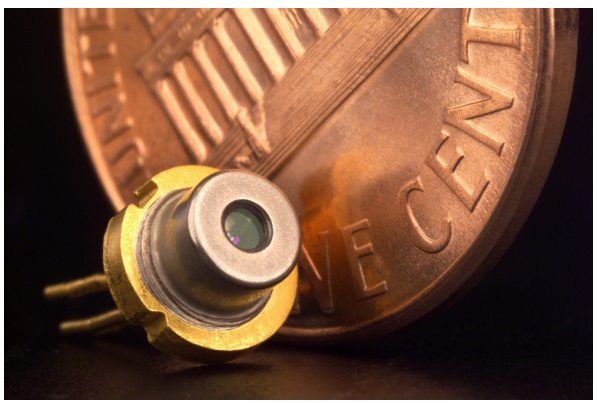


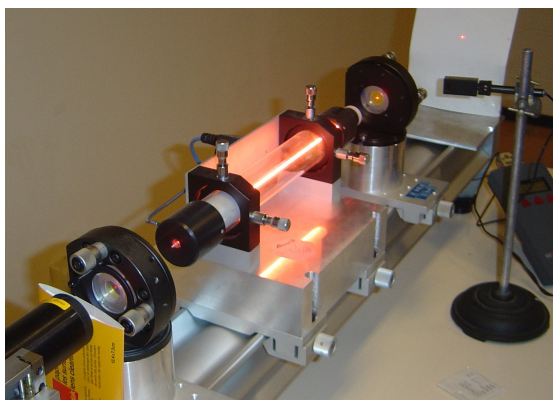
lasers 101 (3)

different types of lasers vary mostly in gain medium:

- solid state lasers (e.g. Nd:YAG, Ti:Sa)
- semiconductor lasers (e.g. InGaN, AlGaAs)
- gas lasers (e.g. HeNe, CO_2)
- dye laser (e.g. rhodamine 6G)







lasers 101 (4)

different lasers types vary in

- **Performance characteristics:** wavelength, output power, line width
- **physical package:** size, weight, complexity (e.g pump mechanism, cooling...)

➜ application requirements defines laser types

lasers 101 (5)

common applications:

- measurements: distance measuring, spectrometers, gravimeters
- optical data transmission
- multimedia: display technology, laser pointer
- focused energy: laser cutting, welding, writing, printing

not only on earth at home, industry, medicine, but also in space

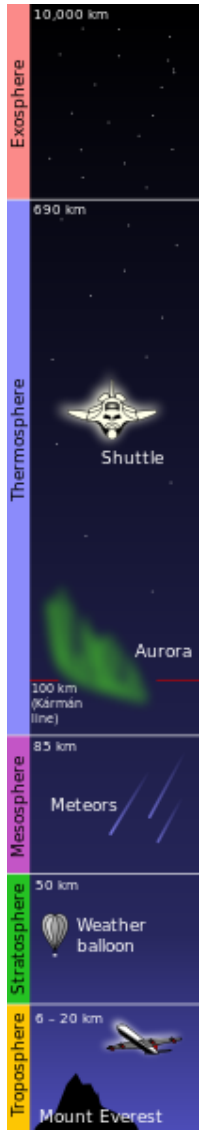
Outline

definition of space

- Definition of **Fédération Aéronautique Internationale (FAI)**: Kármán-Line at 100 km MASL
- Definition of **US NACA in 1950**: 50 mi (approx. 80 km)

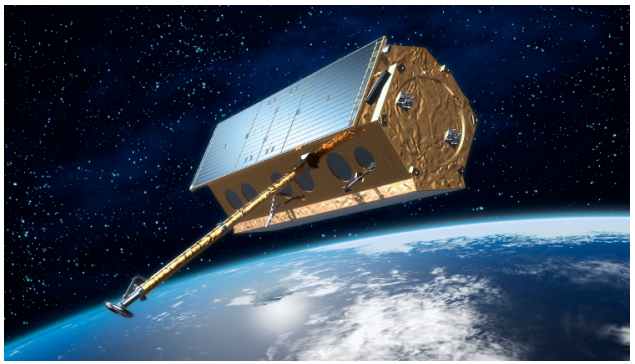
ways into space:

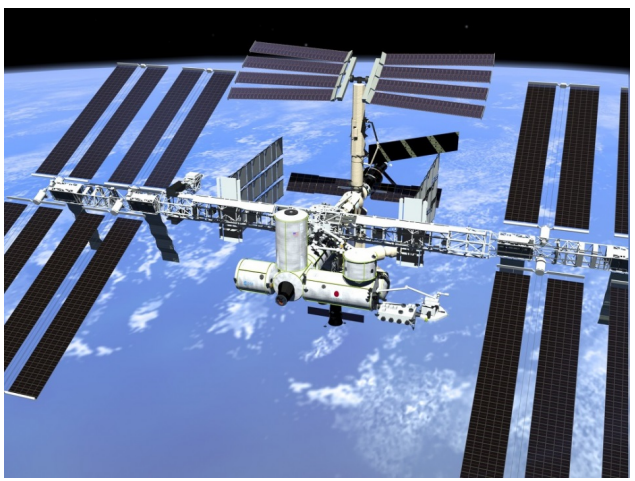
- satellites
- space station
- orbiter
- sounding rockets



applications in space

- Observation (e.g of distant galaxies, earth meteorology)
- Communication (telecommunication)
- Science (e.g. experiments in μ-gravity)
- Navigation (e.g. GPS)
- Military or "defence"



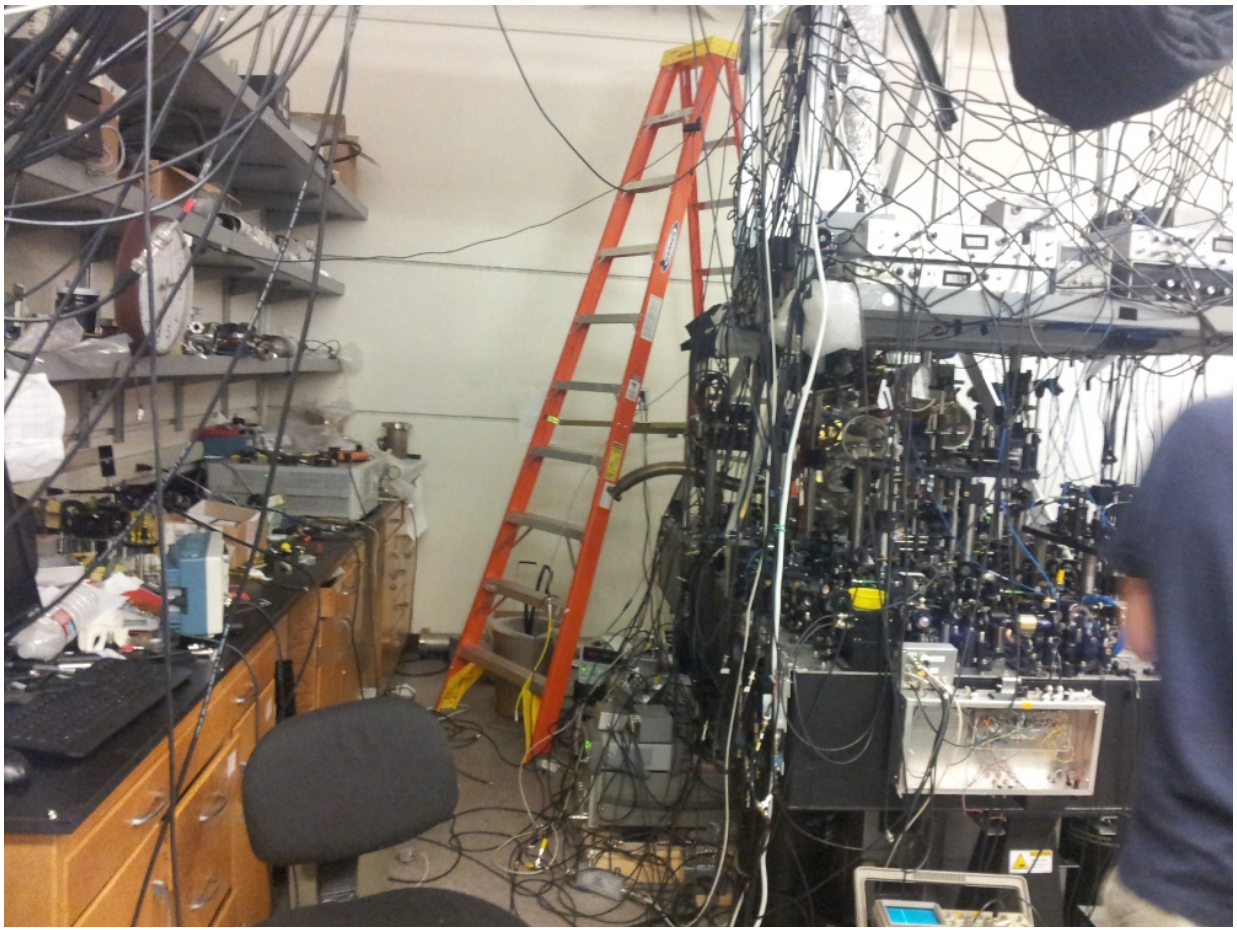


restrictions in space

High launch costs and limited resources and special environment in space result in strict specifications concerning:

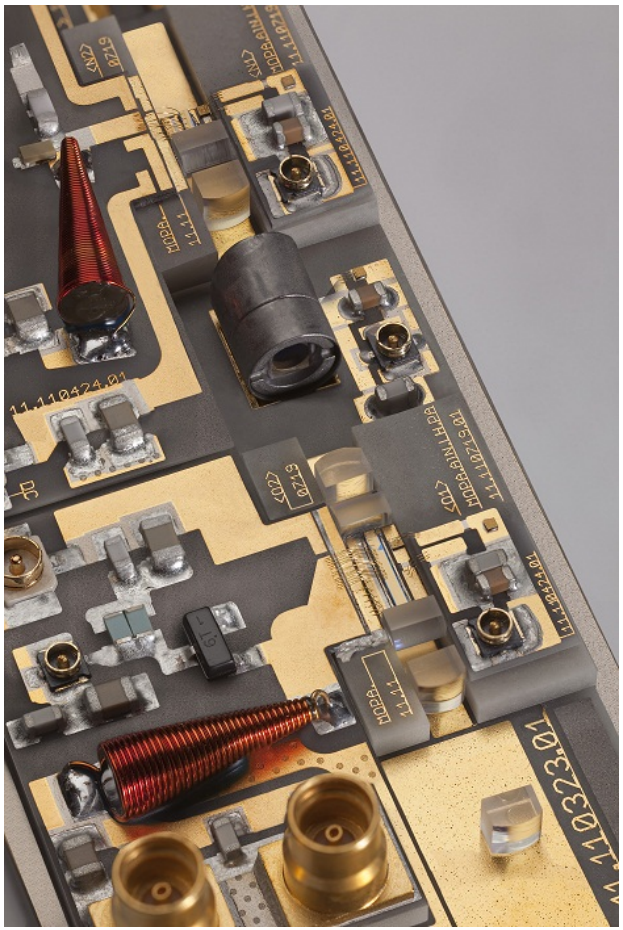
- size & weight
- power consumption budget
- mechanical robustness
- radiation resistance
- autonomy
- live time

laser experiment setup on earth

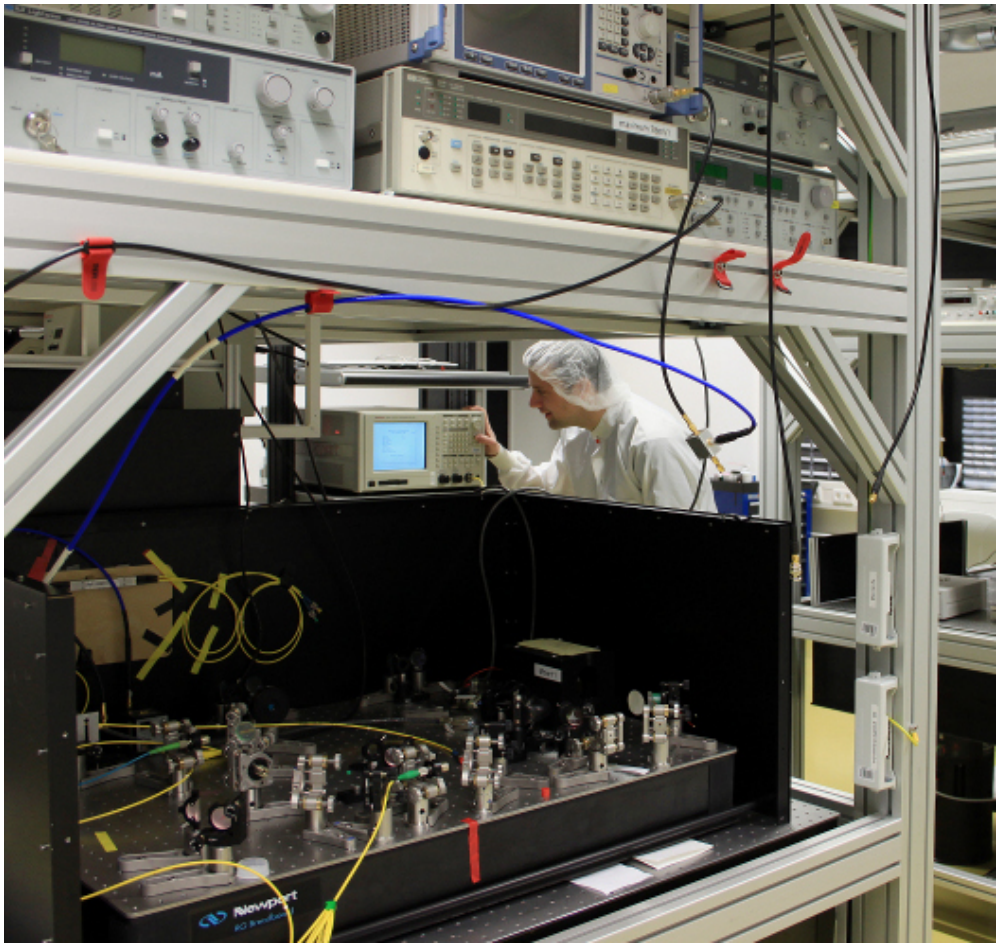


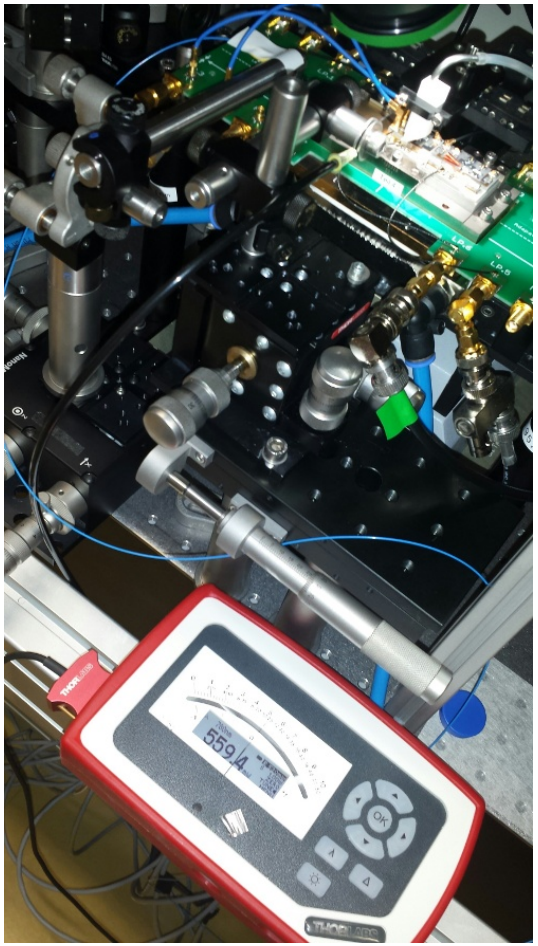
integration

- choose appropriate technology
- choose space qualified components
- take care of out gassing materials
- miniaturize every component
- no movable parts where possible
- create clean integration environment
- test & characterize
- document everything



our lab

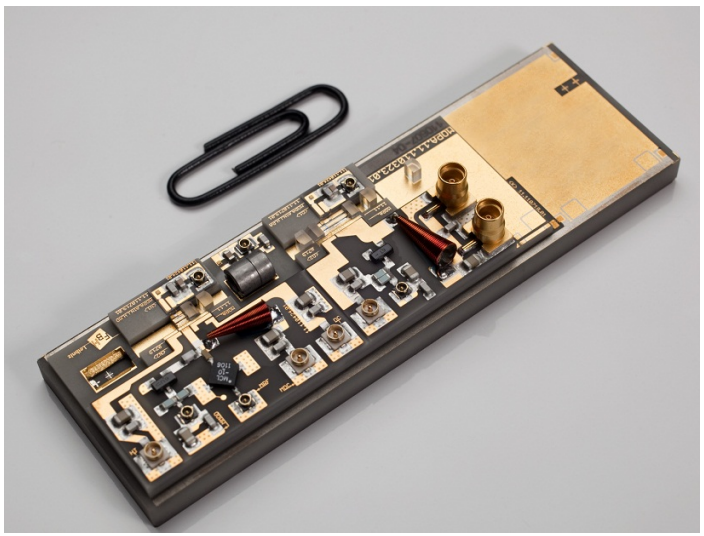




example: MAIUS MOPA

- semiconductor based Master Oscillator Power Amplifier module
- AlN bench with footage of 80 x 25 mm, electrical interface included, weight: 15 g

- no movable parts
- wavelength 780.24 nm, tuning range 1.4 nm
- output power > 1.2 W, efficiency of $> 22\%$



standards and testing procedures for space hardware

to ensure uniform level of quality and reliability suitable to application and environment. e.g. MIL-STD-883 (test method standard microcircuits) defines

- purpose of a test
- apparatus, test conditions,
- test procedures and failure criteria

test methods

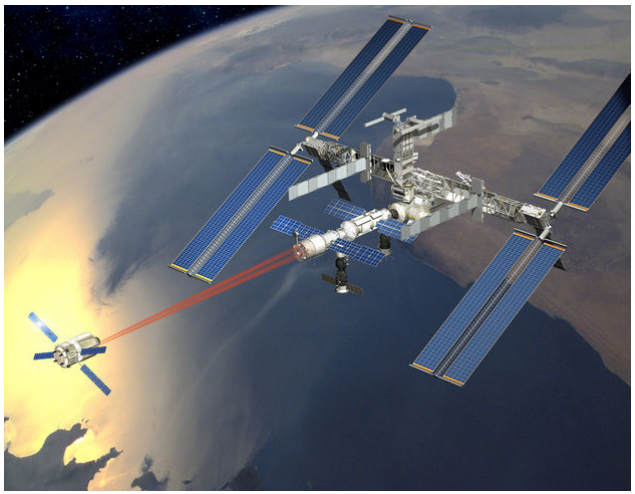
- environmental tests (e.g. pressure, temperature cycling and shock)
- mechanical tests (e.g. acceleration, vibration, shear strength)
- electrical tests (load conditions, ESD sensitivity)

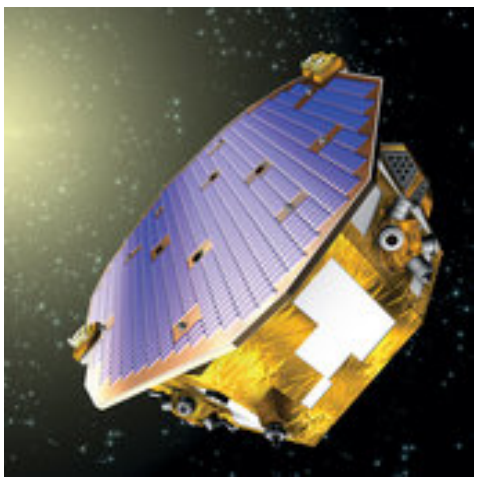
Outline

optical measurement (1)

interferometry

- Light detection and ranging (LIDAR)
- evaluate interference of reflected beam
- e.g. to measure distances as in docking operations with ISS, mapping surfaces, analysing atmosphere
- e.g. to measure gravitational waves as in Laser Interferometer Space Antenna (LISA) (now: proof-of-concept mission, LISA Pathfinder (LPF), scheduled in 2015)





optical measurement (2)

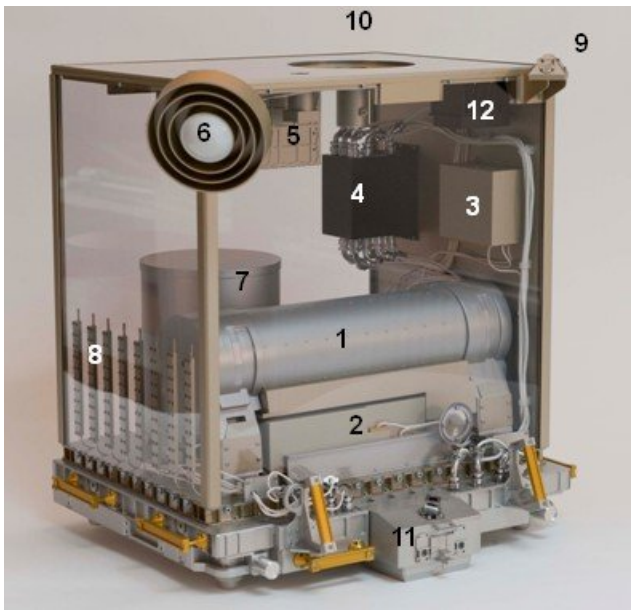
spectroscopy

- stimulation of electrons to higher energy level
- evaluate absorption of beam or emission of relaxing photons
- e.g. Laser-induced breakdown spectroscopy (LIBS) and tunable laser spectrometer (TLS) on Curiosity (launched in 2011)

optical measurement (3)

optical references: atomic clocks

- timekeeping element: electronic transition frequency in the optical region of the EM spectrum of atoms
- primary standards for international time distribution services, to control the wave frequency data transmission, GPS, etc.
- new generation in space: Atomic Clock Ensemble in Space (ACES) (ISS, orig. scheduled end 2013)



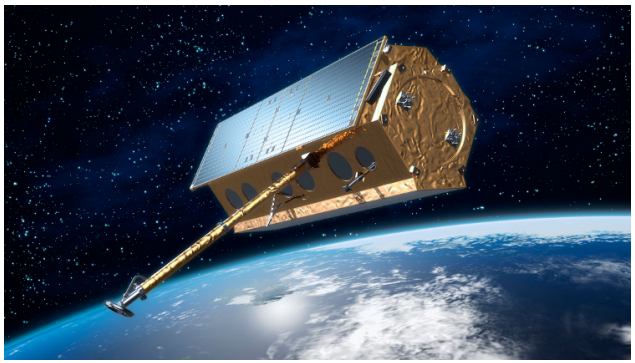
free space optical communication (1)

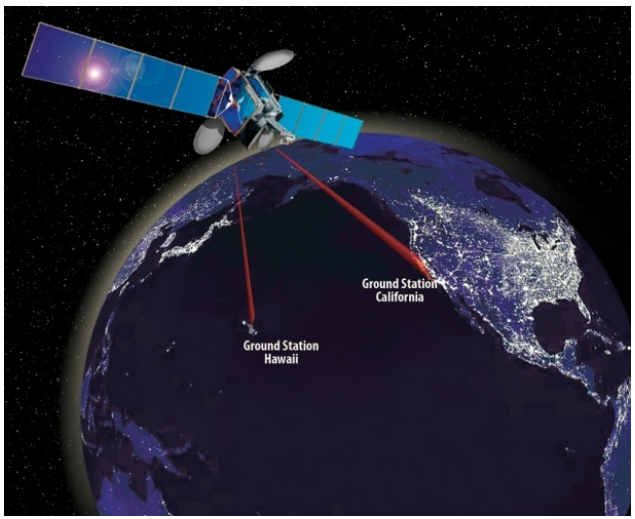
facts

- modulation via phase shift keying (PSK) or binary on off keying (OOK) of data on optical carrier (laser beam)
- compared to RF-transmission:
  - longer distances,
  - less power,
  - higher transmission rate
- still: dependent on atmosphere and weather

free space optical communication (2)

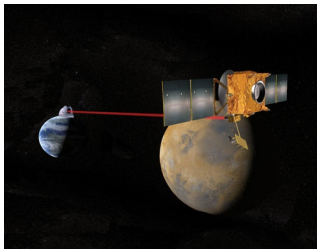
- Laser Communication Terminal (LCT)
  - first tested in satellite ARTEMIS
  - downlink 50 Mbps in 2001
  - inter-satellite 50 Mbps in 2001
  - inter-satellite **5.5 Gbps** (TerraSAR-X and NFIRE in 2008)
- Lunar Laser Communications Demonstration mission (LLCD) on the Lunar Atmosphere and Dust Environment Explorer (LADEE) (launched 2013-09-07): downlink **622 Mbps**

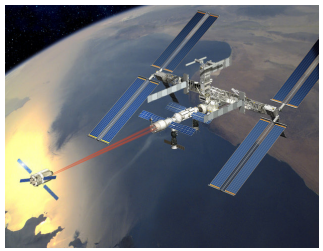




summary

- lasers are cool
- lasers have a lot of applications, even in space
- reaching space is challenging
- ... but not impossible!





space for all

- http://www.amsat.org/
  amateur radio satellite organizations worldwide
- http://www.rexusbexus.net/
  sounding rocket and balloon experiments for students
- http://cubesat.org/
  1 l satellites project
- http://www.googlelunarxprize.org/
  lunar rover competition
- http://www.hobbyspace.com/
  webguide to space hobbies and activities

thank you!