

THE BRIJUNI CONFERENCE

exploring fundamental problems in science

NATO ARW

Imaging in space and time

28.8. – 1.9.2006

Laser and Computer assisted Surgery **Facial topometry using pulsed holography**

Outline:

- **ILM short overview**
- **Ultra fast holographic facial reconstruction for granio maxillo facial surgery**
- **New precise navigated laser osteotomy (short)**

Peter Hering

*Institut für Lasermedizin der Universität Düsseldorf and
Stiftung caesar, Bonn*

www.ilm.uni-duesseldorf.de, hering@uni-duesseldorf.de

www.caesar.de, hering@caesar.de

founded 1991 as an interdisciplinary institute in the medical faculty

„theoretical“ institute without patients

cooperation with physician, biologist, chemist and physicist

teaching:

Laser medicine for physicians

Training courses for laser safety and medical application

Course in physics department: Laser medicine for physicists (physics diploma)

Main research areas:

analytical, diagnostical and therapeutical use of lasers in biomedicine and environmental research

Trace gas analysis, computer and laser assisted surgery, 3d imaging, LITT, dosimetry with photon density waves, minimal-invasive surgery, spectroscopy in turbid media, Monte Carlo Simulation and dosimetry

close cooperation with many **clinical** institutes

Naevus Flameus with light guides

Laser lithotripsy with automatic stone recognition (LIBS)

new spectroscopic methods:

- Breath test analysis (NDIR, CRDS)
- Photon density waves for LITT with online control for tumour treatment
- control of physiological parameters: oxygen saturation in blood and flux simultaneously

new 3D imaging methods:

Coronary artery and pulsed holography

aim: Multi modal data

→ **image guides surgery**



Trace Gas Analysis



Trace Gases



to mark the reason:



The Nobel Prize in Physiology or Medicine 2005

"for their discovery of the bacterium *Helicobacter pylori* and its role in gastritis and peptic ulcer disease"



Barry J. Marshall

🏆 1/2 of the prize

Australia

NHMRC *Helicobacter pylori*
Research Laboratory, QEII
Medical Centre; University of
Western Australia
Nedlands, Australia

b. 1951



J. Robin Warren

🏆 1/2 of the prize

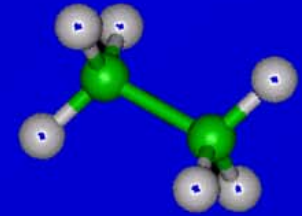
Australia

Perth, Australia

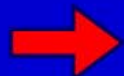
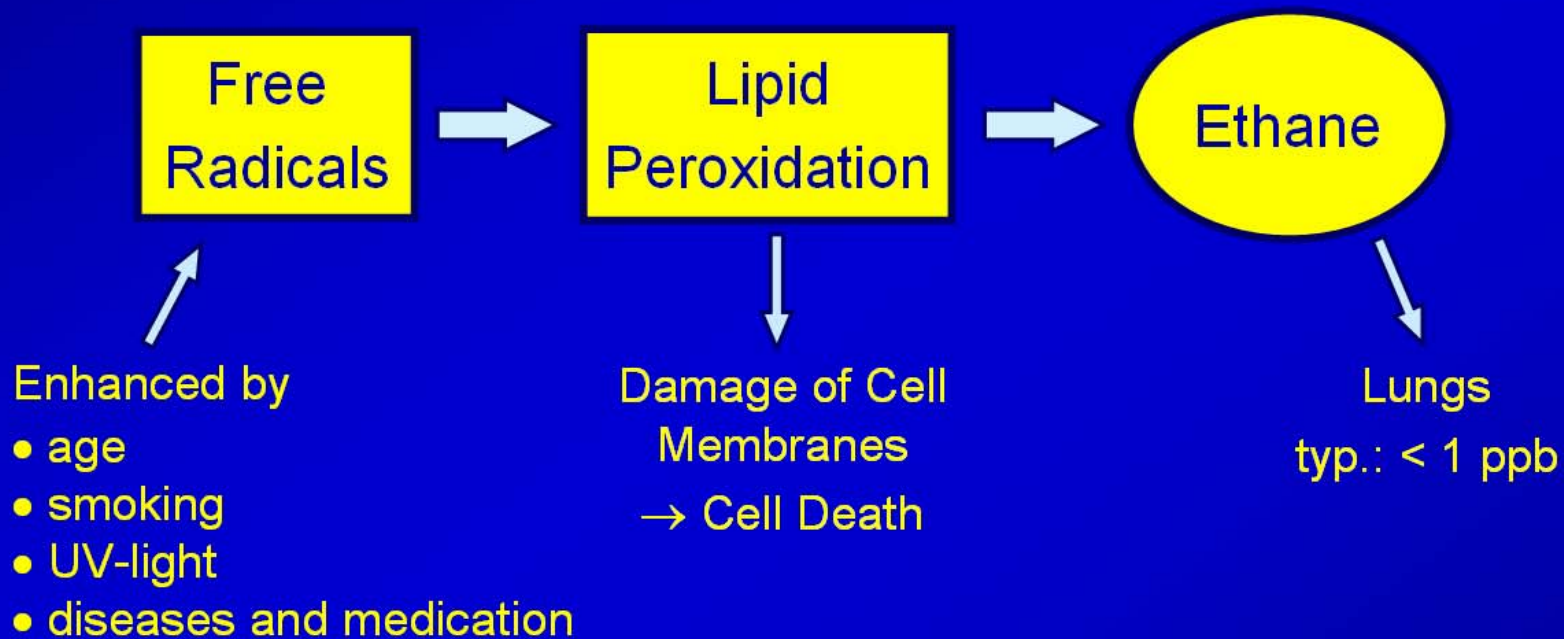
b. 1937



Ethane in Exhaled Human Breath



Path way:



Ethane is a marker for the oxidative stress status

CALOS Detection Limits

<i>Molecule</i>		<i>Detection Limit ppt</i>	
<i>Ethane</i>	C_2H_6	6 (0.3)	
<i>Methane</i>	CH_4	200	
<i>Ethylene</i>	C_2H_4	500	
<i>Formaldehyde</i>	H_2CO	1000	
<i>Nitric Oxide</i>	^{14}NO	800	
	^{15}NO	40	
<i>Carbon Monoxide</i>	CO	90	
<i>Carbonyl Sulfide</i>	OCS	3	

Up to Date: Jan 2006

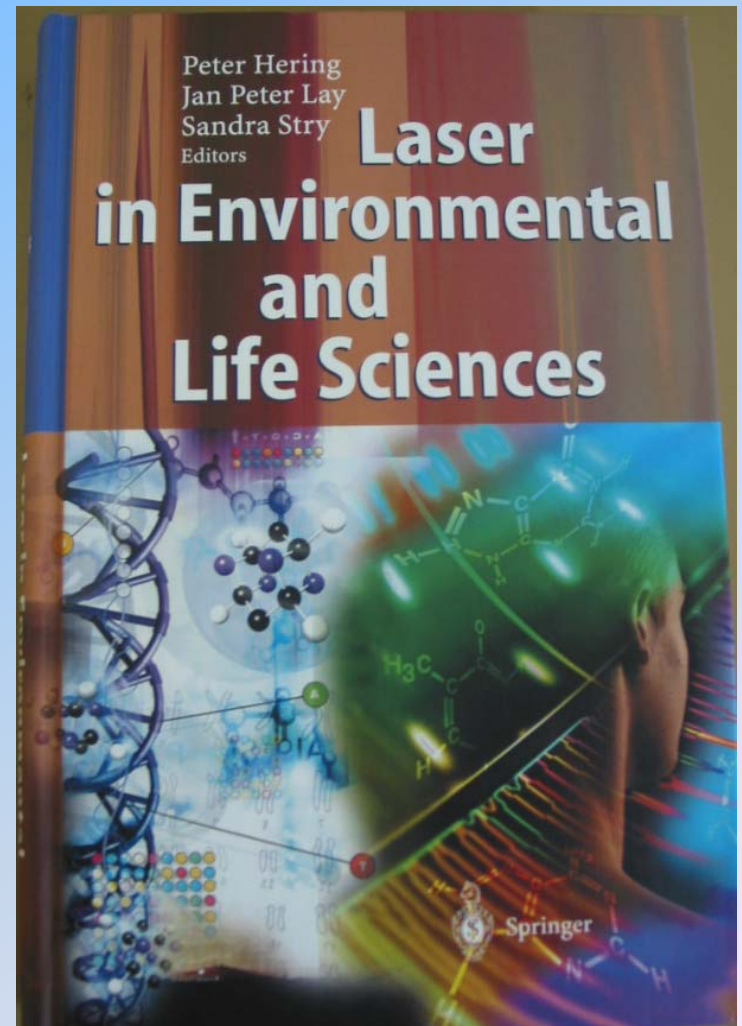
Book available
Springer 12/2004

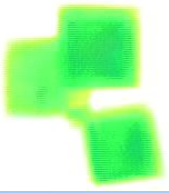
all our publications are downloadable
in the pdf format under

www.ilm.uni-duesseldorf.de/tracegas

more information:

hering@uni-duesseldorf.de





**center of advanced european studies and research, Bonn
Start 2000**

scientific research priorities

1. Nanoscience

2. Linking of Electronic and Biological Systems

3. Ergonomics in Communications

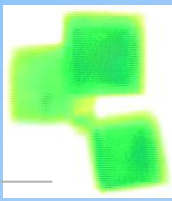
Computer and laser assisted surgery

human - machine interactions in complicated surgeries

caesar

center of advanced european studies and research, Bonn





The research triplet **Laser and Computer Aided Surgery** is build up by the

- 👉 modeling and simulation group - **Surgical Simulation and Navigation**
- 👉 the experimental group - **Holography and Laser Technology**
- 👉 and the engineering group - **Rapid Prototyping**

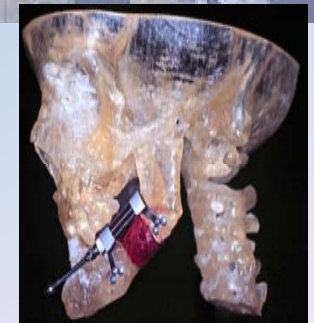
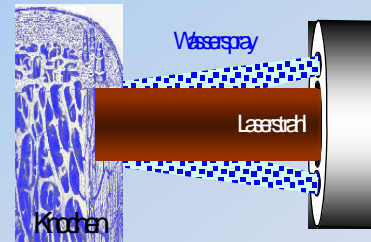
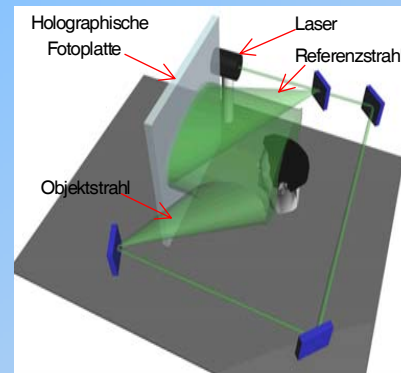
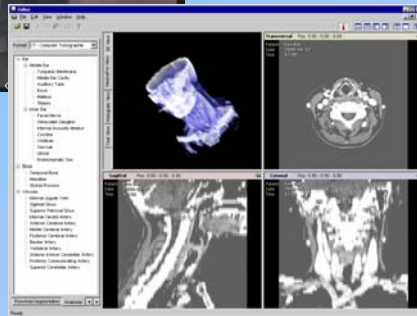


Image guided surgery

- better multi modal imaging methods (MRT, CT, ultrasound, PET, Relief)
- Realistic Rapid Prototyping Models for OP-planning
- better instruments for hard tissue processing
- Navigations systems und robots

Kallusdistraction



Prof. Dr. Dr. F. Zeilhofer

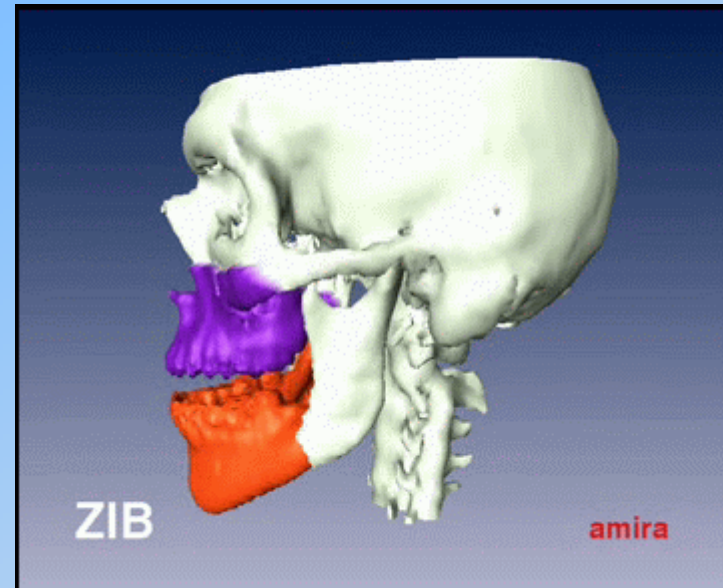
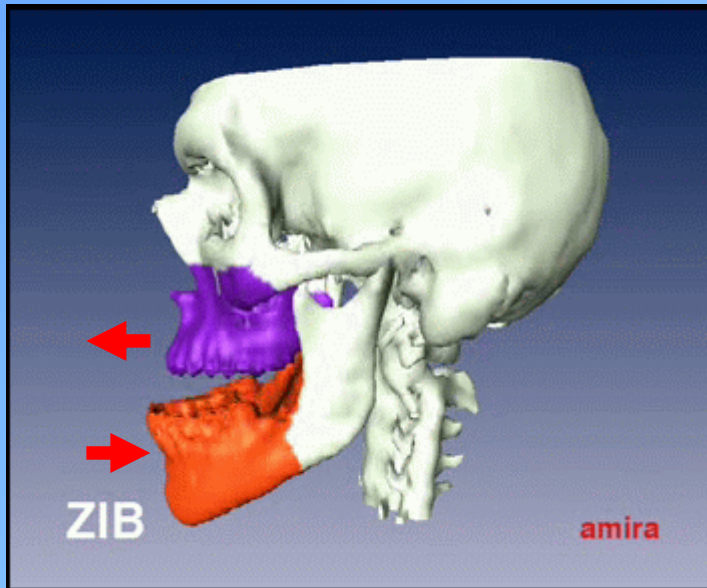
Chirurgie kraniofazialer Fehlbildungen



Bimaxilläre Osteotomie

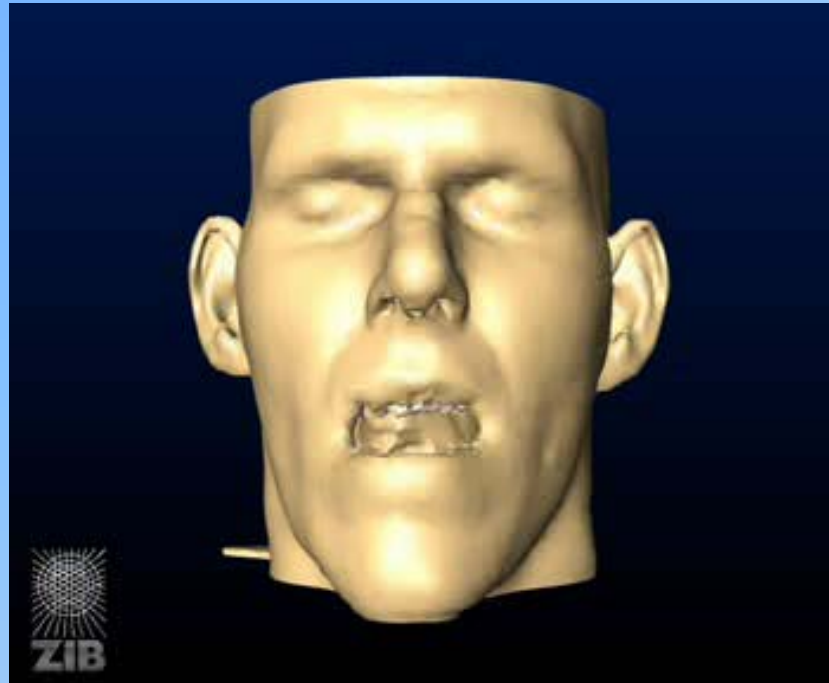


Bimaxillary osteotomy



Figures : Konrad Zuse Institut, Berlin

Bimaxillary Osteotomy



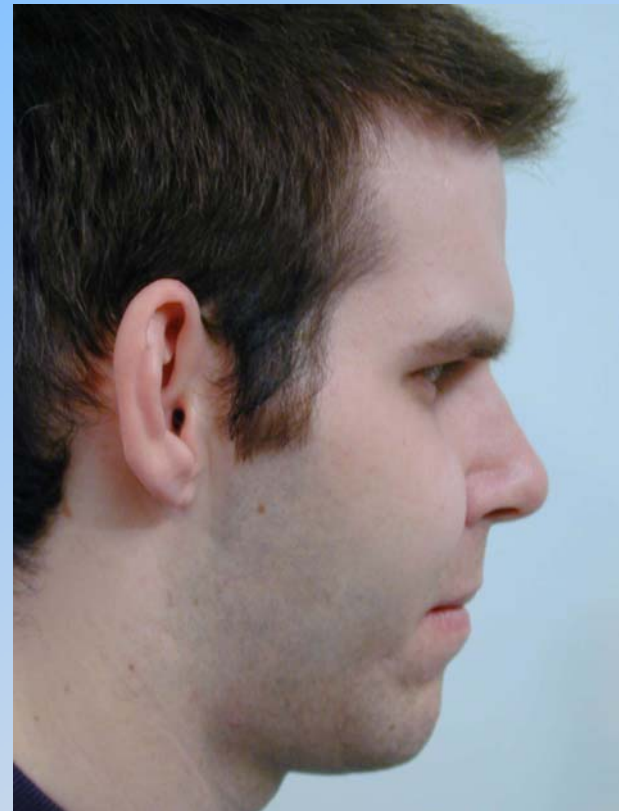
Animation: ZIB Konrad-Zuse-Zentrum für Informationstechnik, Berlin

Prof.Dr.Dr. H.-F. Zeilhofer, Mund-Kiefer-Gesichtschirurgie, Universitätsspital Basel

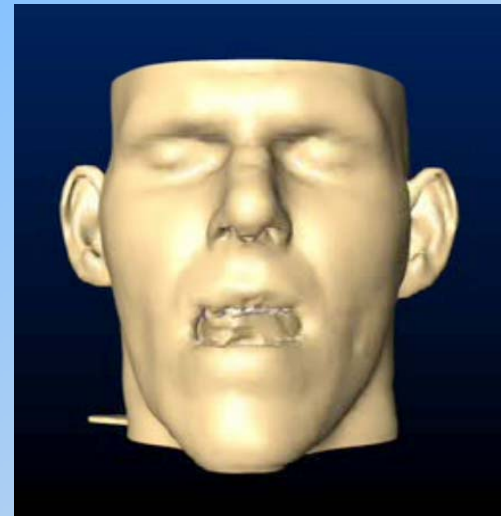
Rapid prototyping model for bimaxillary osteotomy



Bimaxilläre Osteotomie



Bimaxilläre Osteotomie



Differences due to:

- ct resolution (3 mm)
- horizontal position in CT



vertical



horizontal

Ultra fast human face measurements with pulsed holography

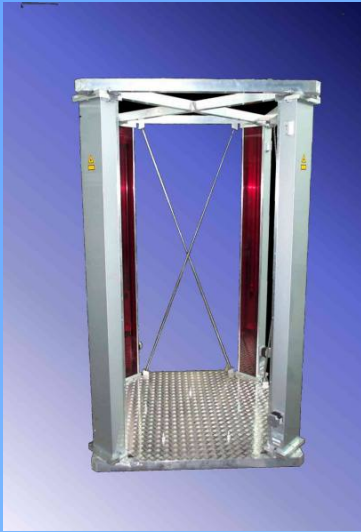


Susanne Frey, Andrea Thelen, Natalie Latriere, Sven Hirsch

former members: Jens Bongartz, Dominik Giel,



Photos of 3D scanner



Vitus
Vitronic



Head & Face Scanner
Cyberware



Tricolite
Steinbichler

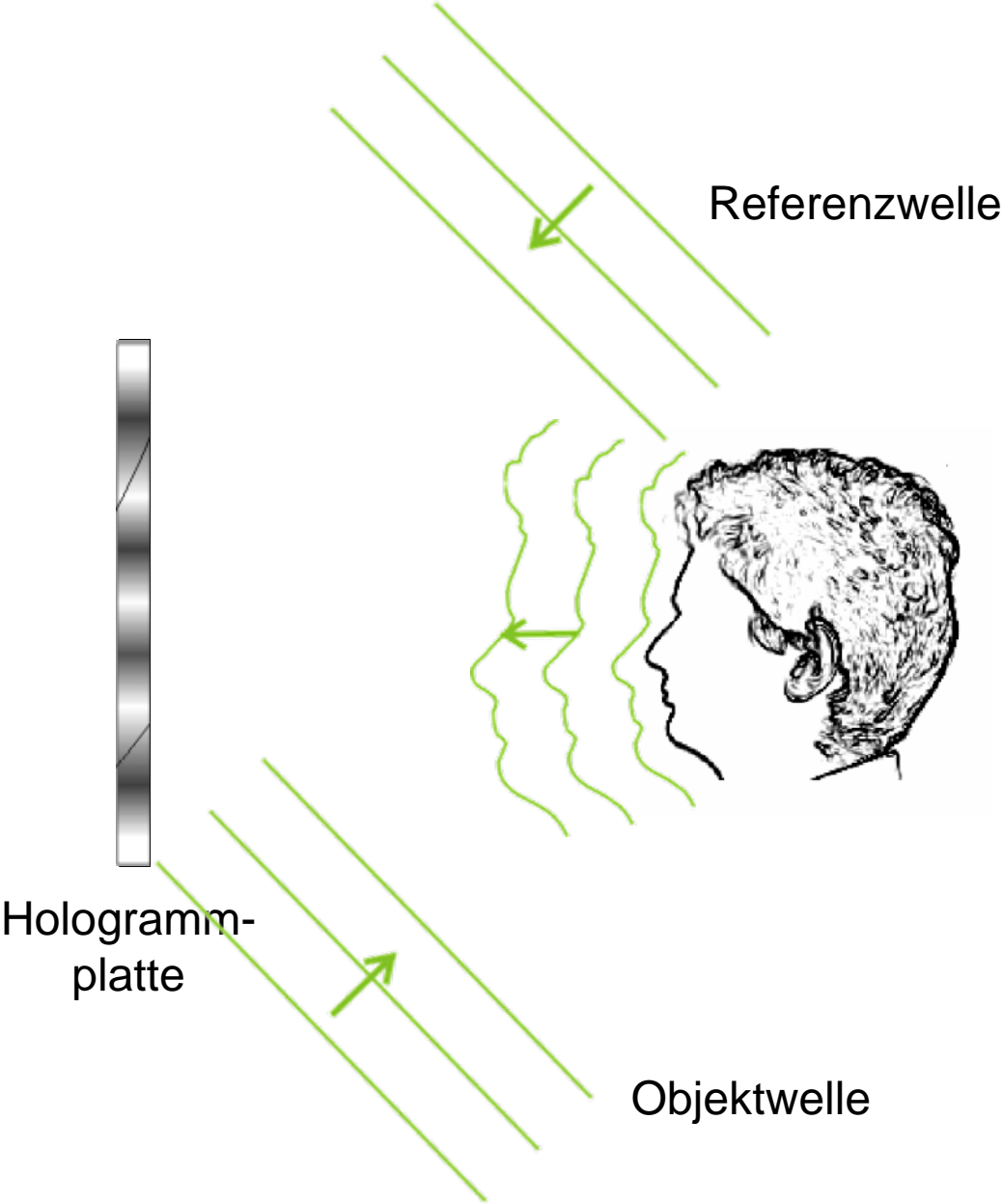
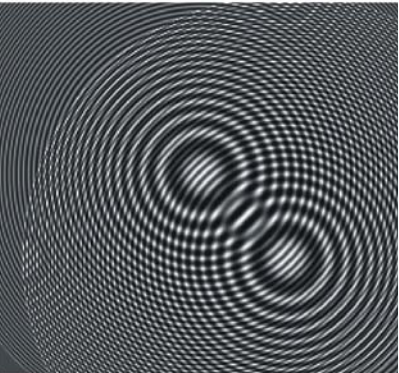


VIVID 900
Minolta

For faces:

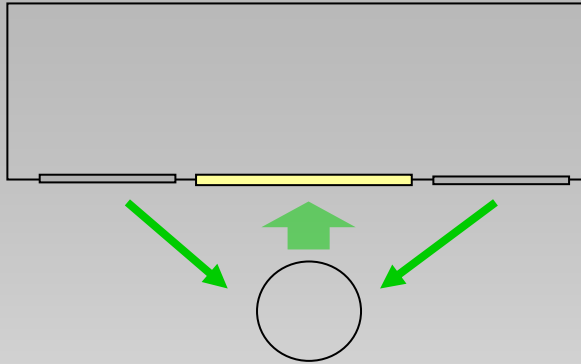
- **Long data acquisition**
- **No real 3D texture**
- **No hair representation**

holographic principle: distorted wave front



Gabor, 1948

Holographic Camera



GEOLA GP-2J

Nd:YLF pulsed

λ : 526,5 nm

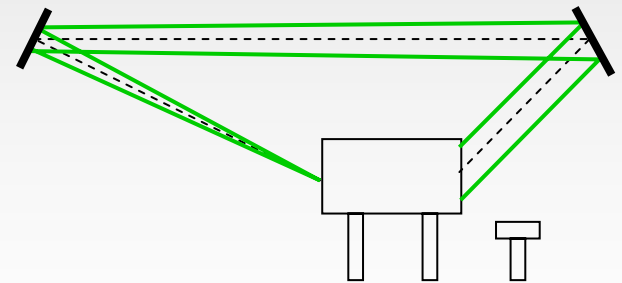
E_p : 2 J

t_p : **35 ns**

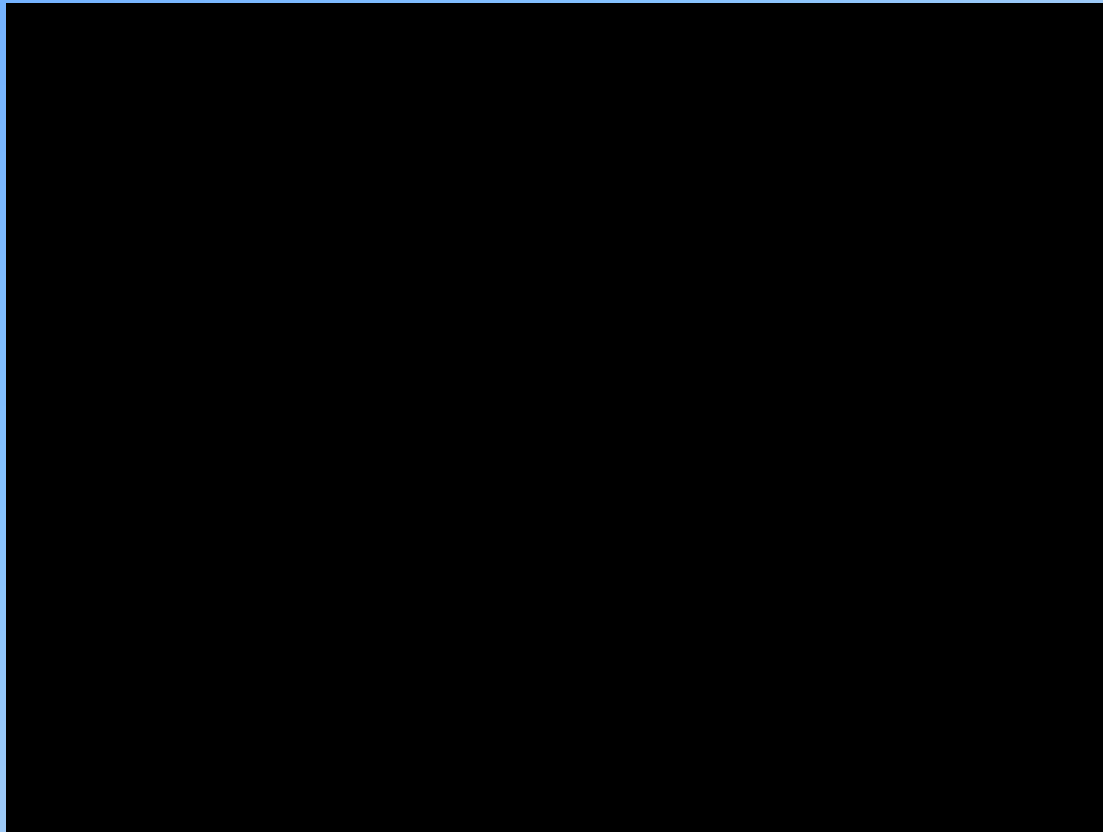
Oscillator-Amplifier
set up

Coherence length:
6m

eye-safe

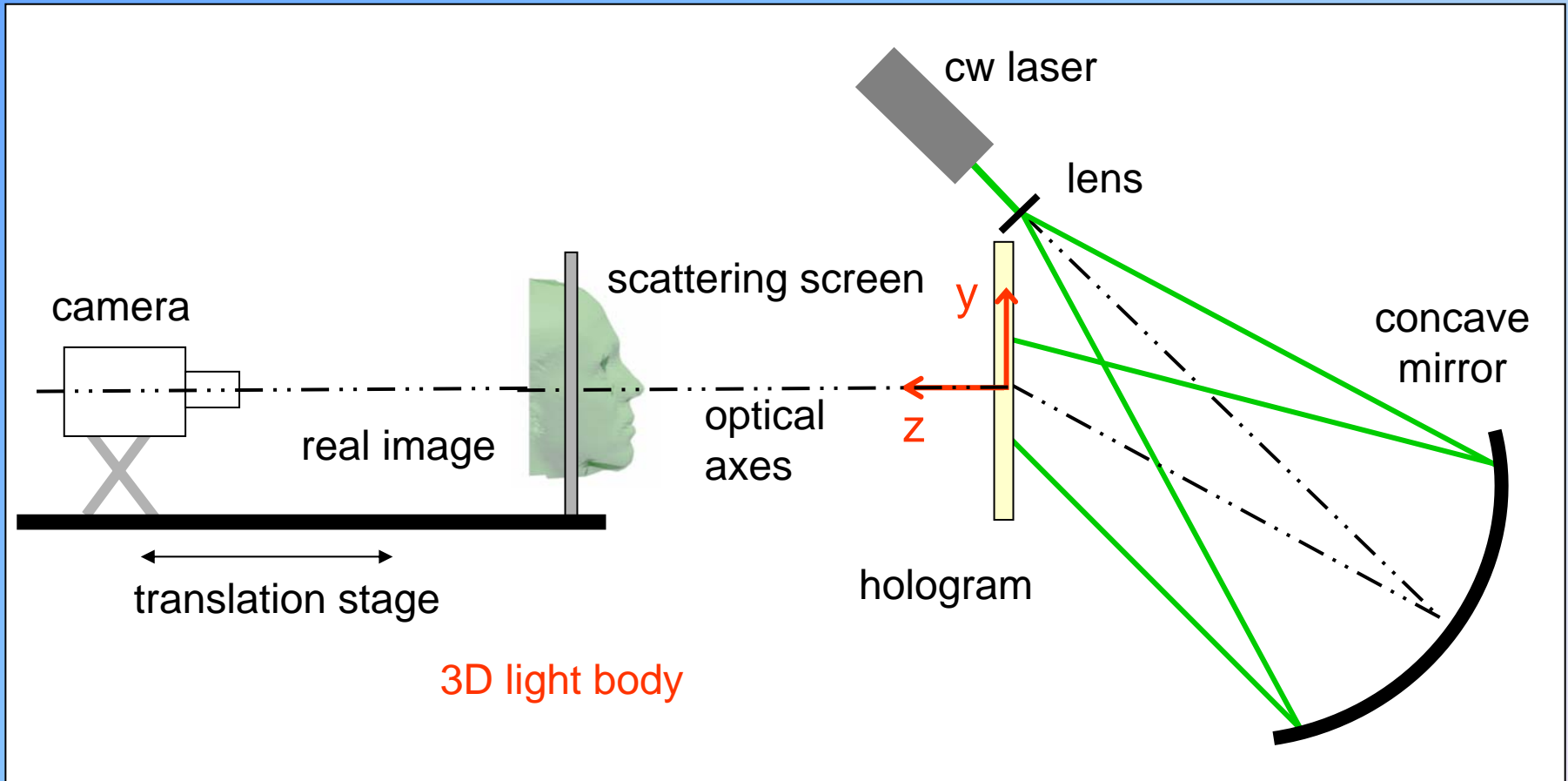


Pulsed hologram recording procedure

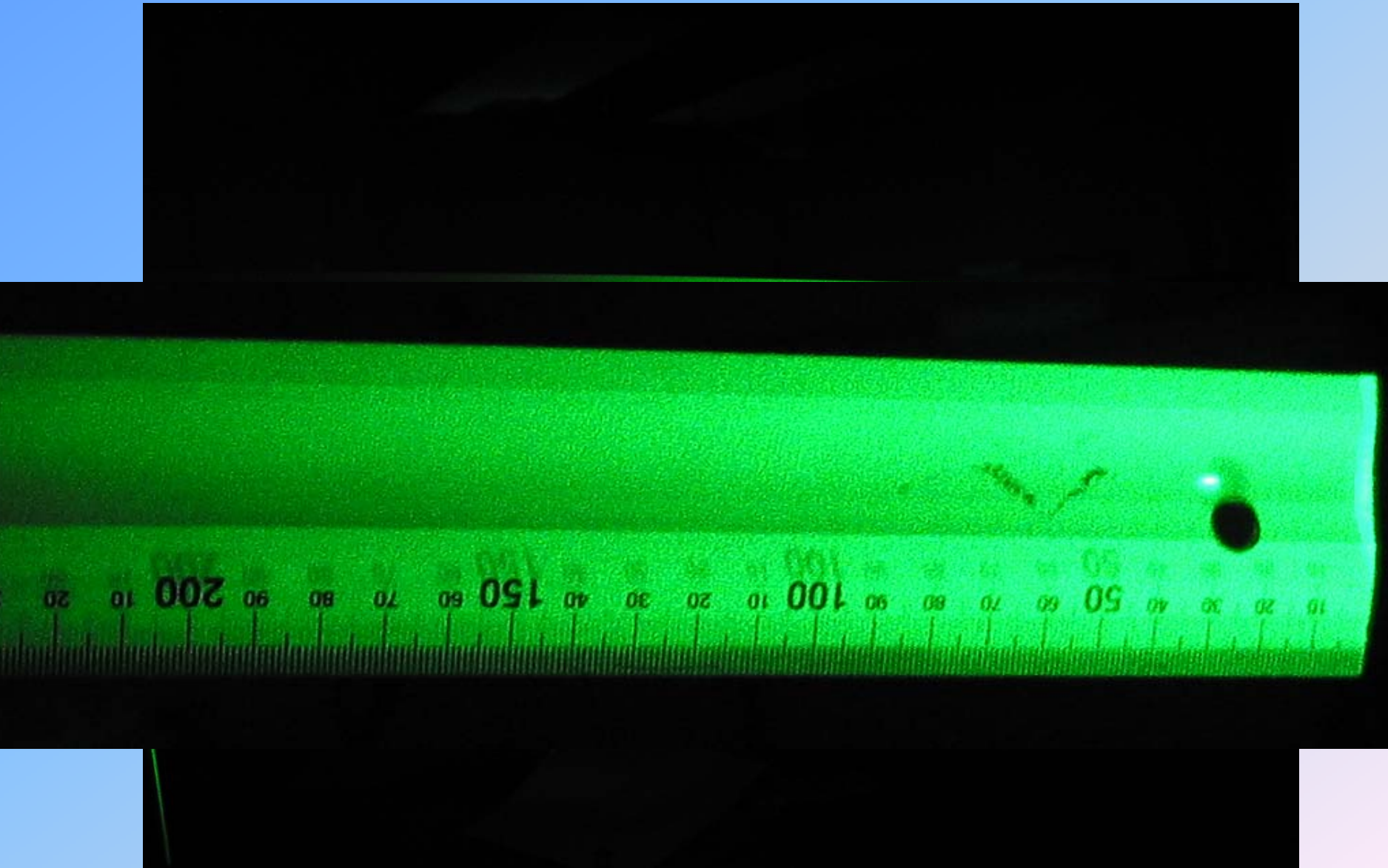


eye safe !! simple

Reconstruction - Digitalisation



reality and virtual reality



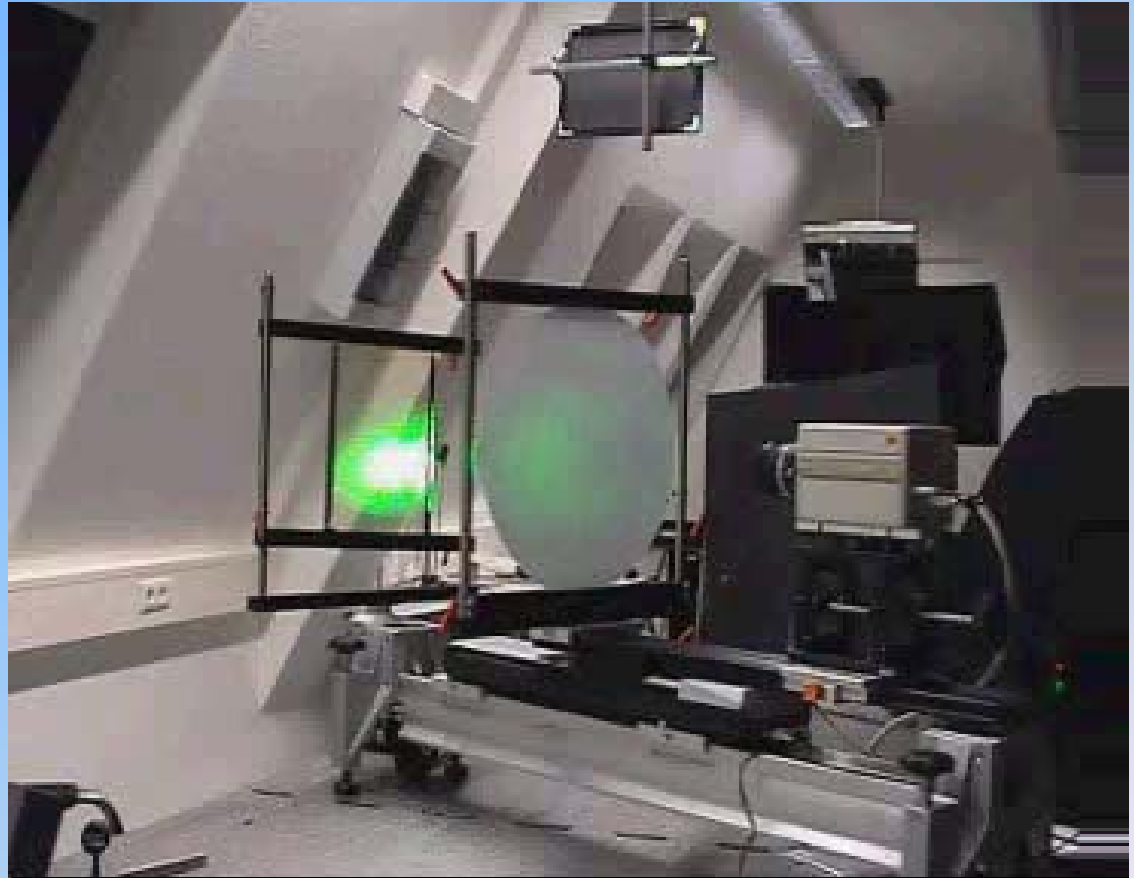
Reconstruction - Digitalisation

reconstructions laser:
Coherent Verdi-V2
532 nm

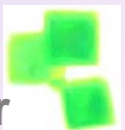
CCD-Chip:
2048 x 2048 Pixel

scattering screen:
thickness 40 μ m

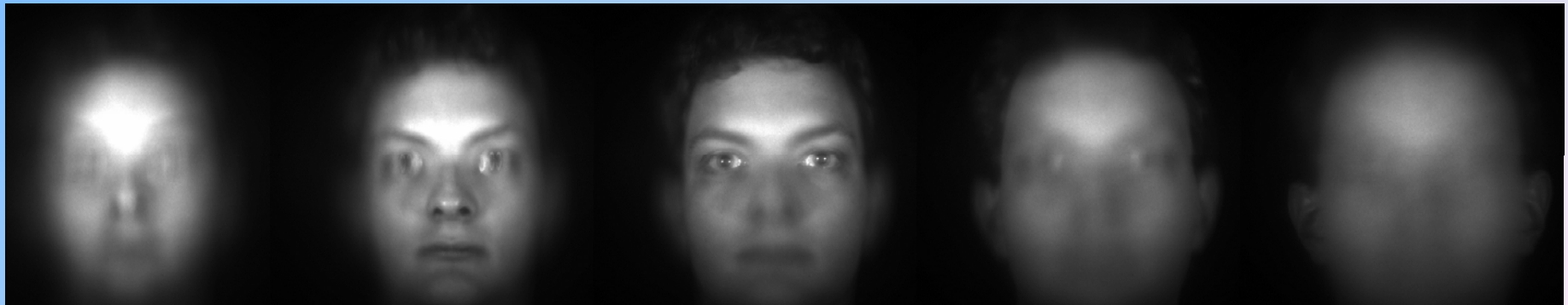
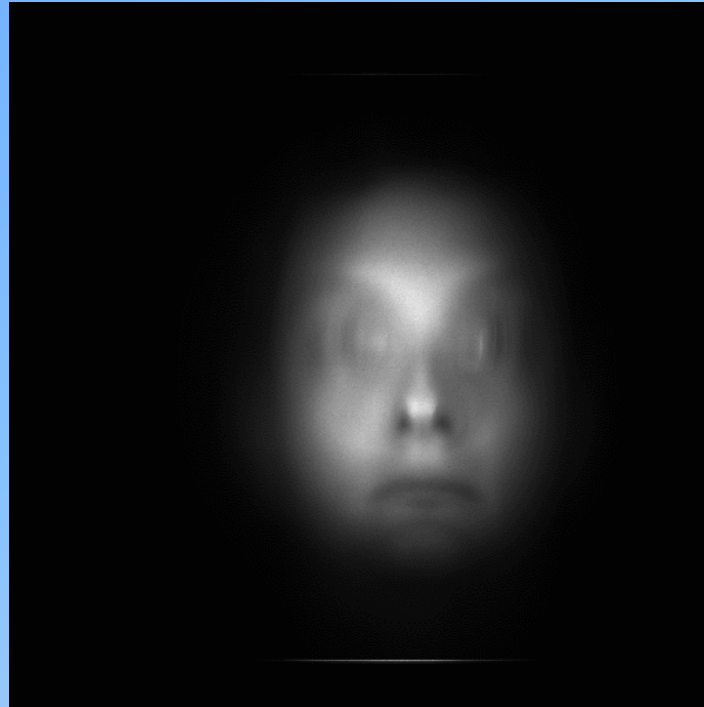
translation stage:
step width 1 μ m



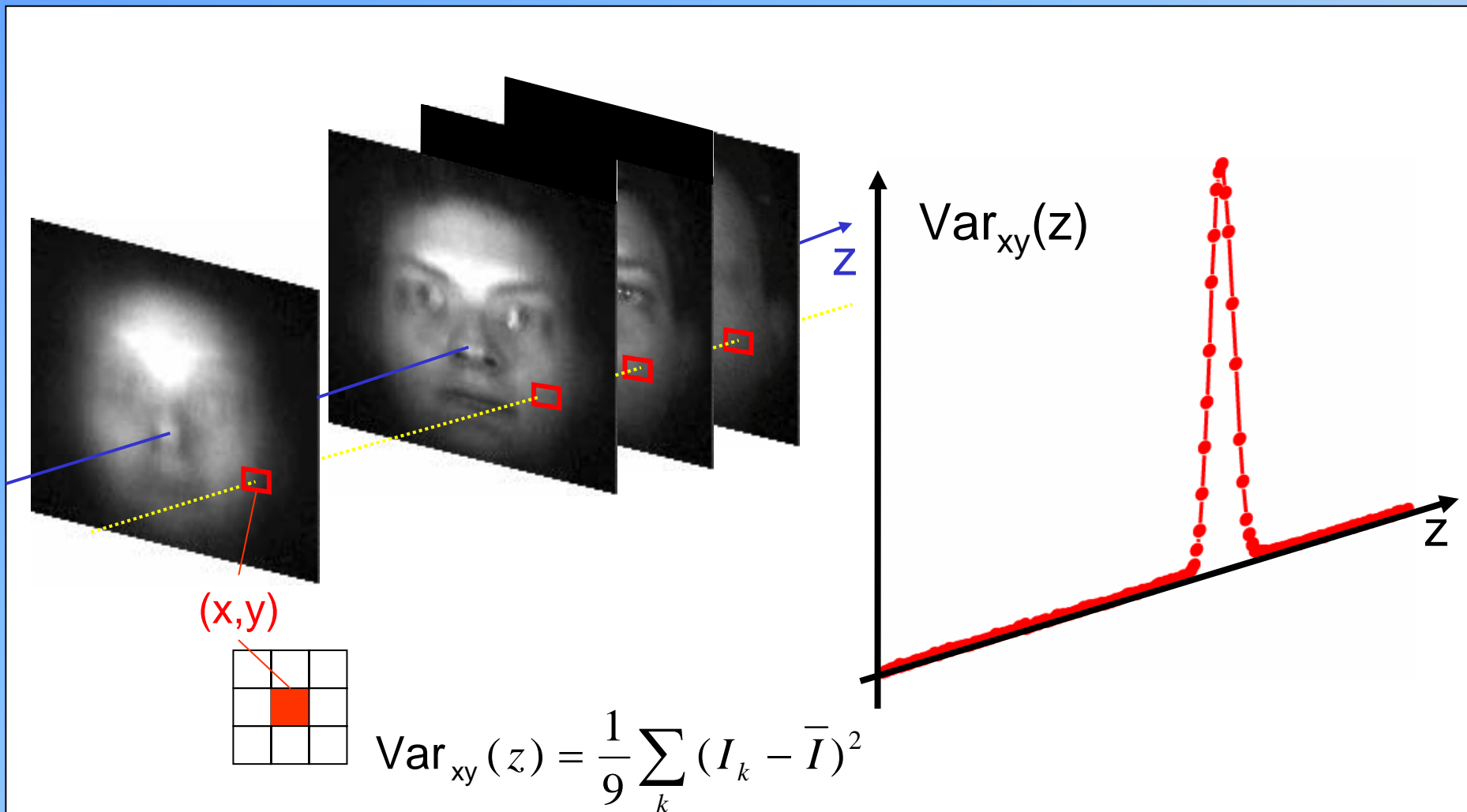
3D light body



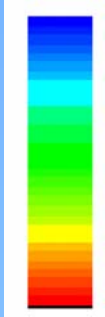
Exemplary projection dataset



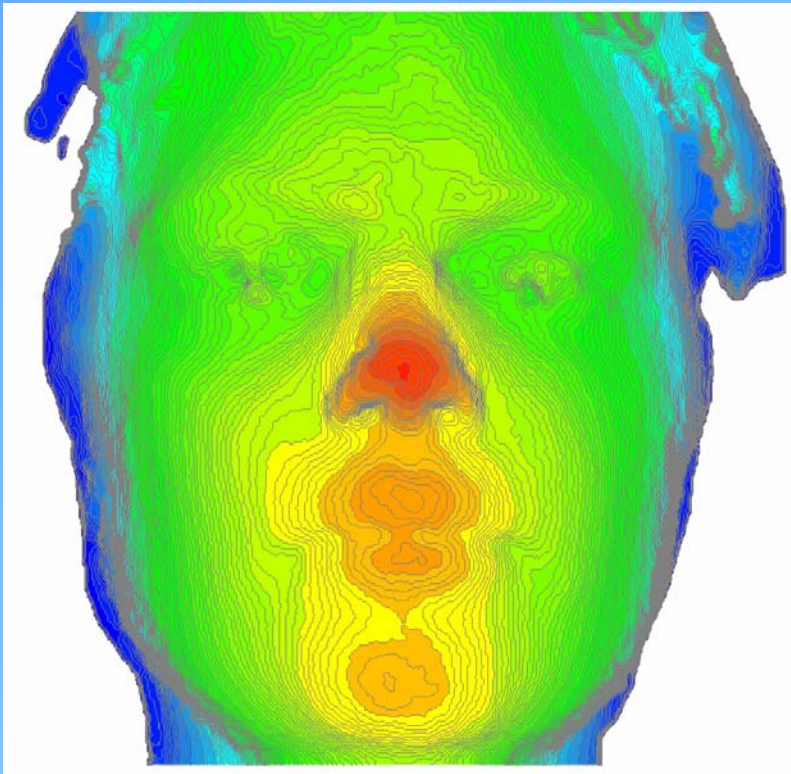
Variance



12cm



0cm

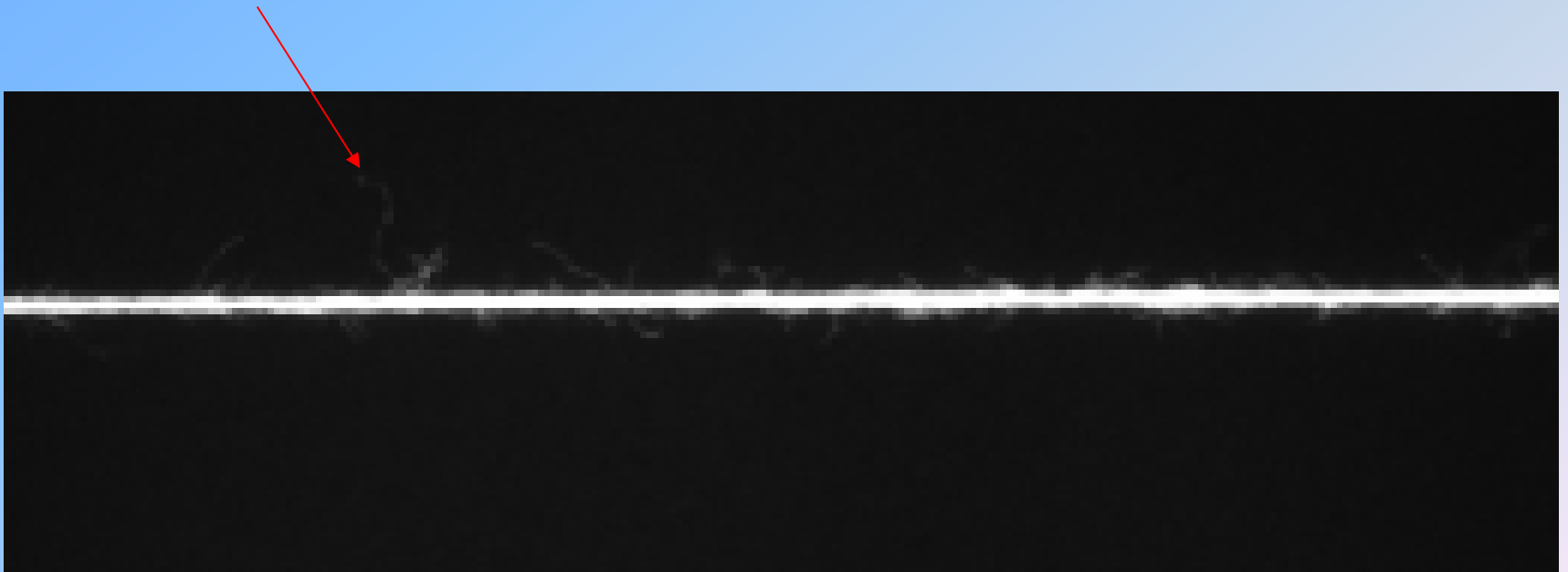
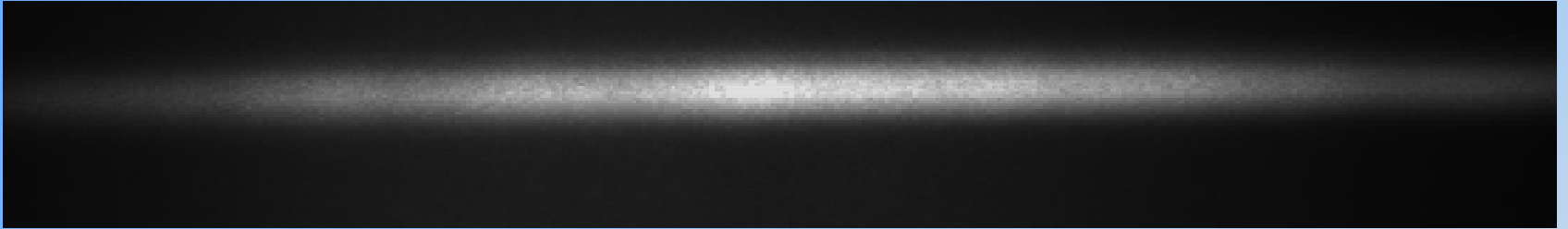


contour map

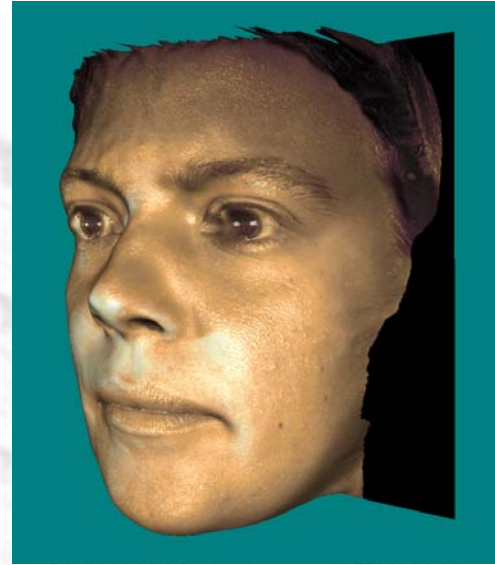


texture

Sequence of a captured string (0.3 mm dia)



Texture:



Show wrl

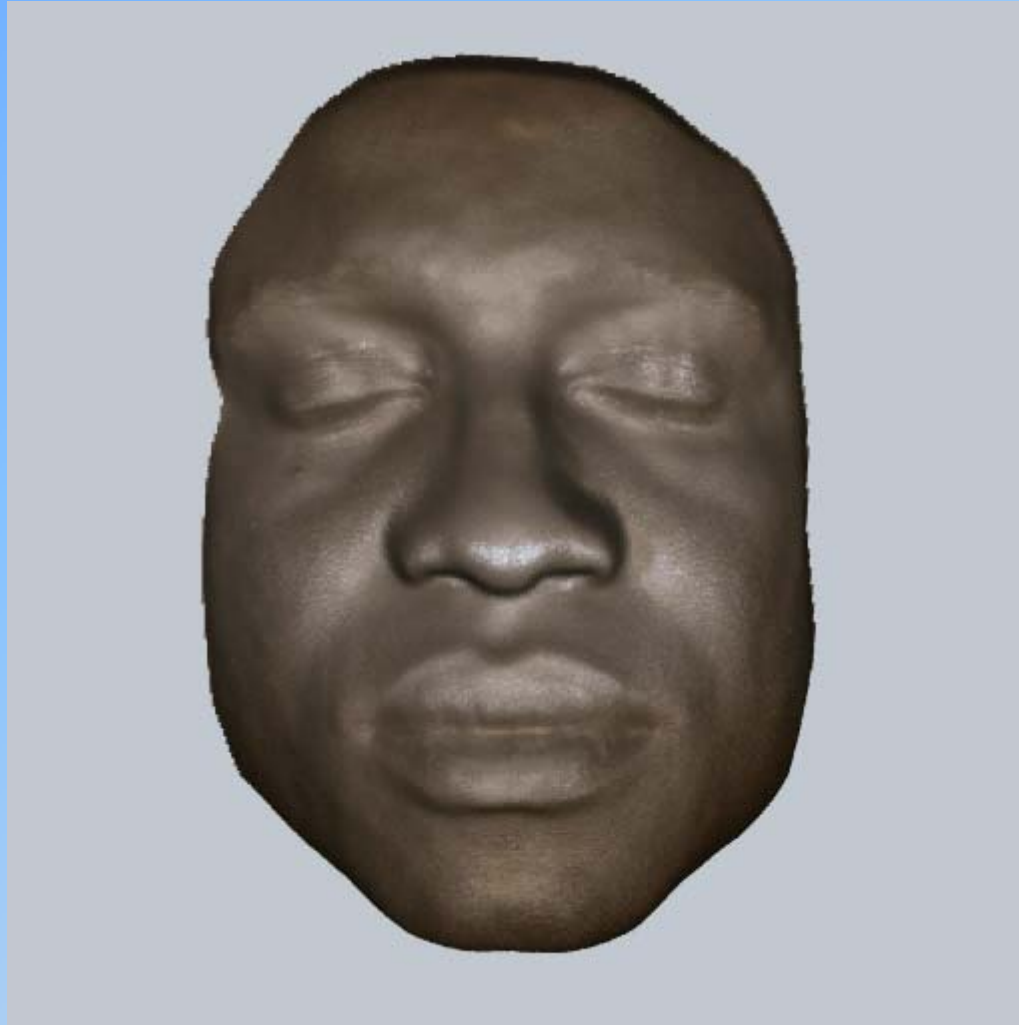
New German Chancellor



New German Nobel Prize Winner



First African 3D reconstruction



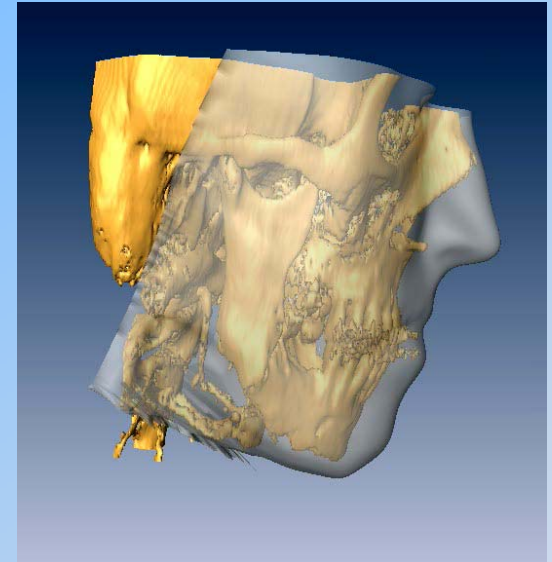
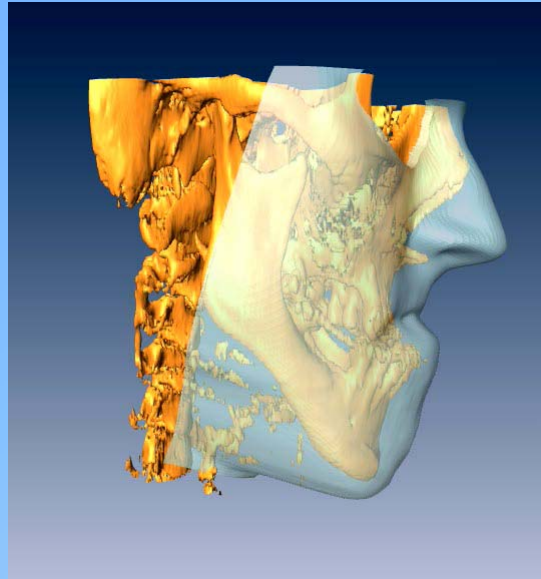
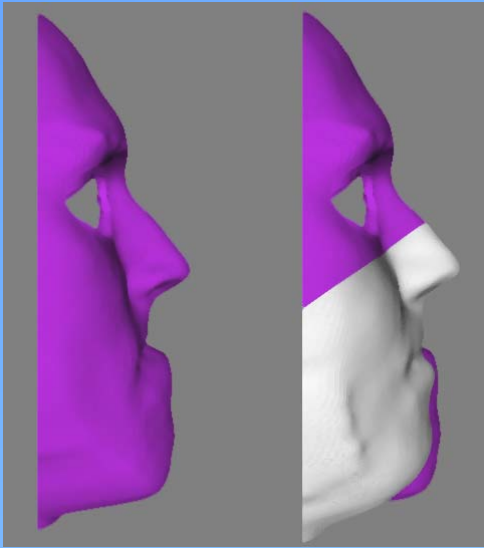
First child - Anophthalmos



High resolution texture

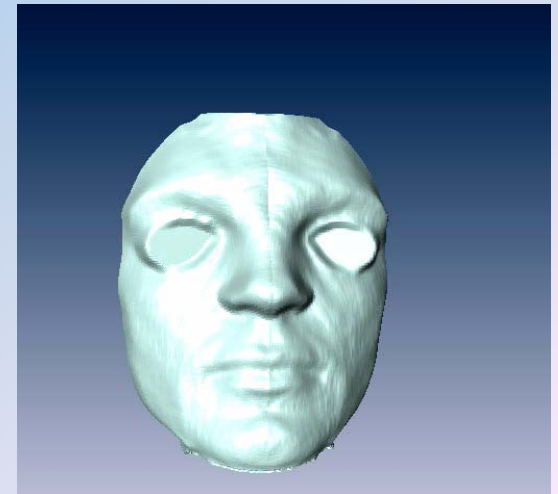
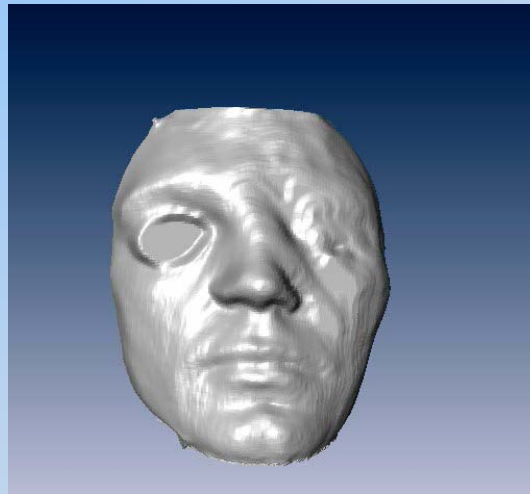


Medical Applications



Surgery documentation, Prof. Fritzeimer , MKG Chirurgie Universitätsklinikum Düsseldorf

Reconstructive surgery
planning,
H.F. Zeilhofer, Basel



Forensics: reconstruction of soft facial parts



Replicas of the skull (caesar RP-Group)

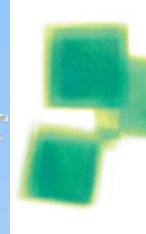
Forensic reconstruction of a living person



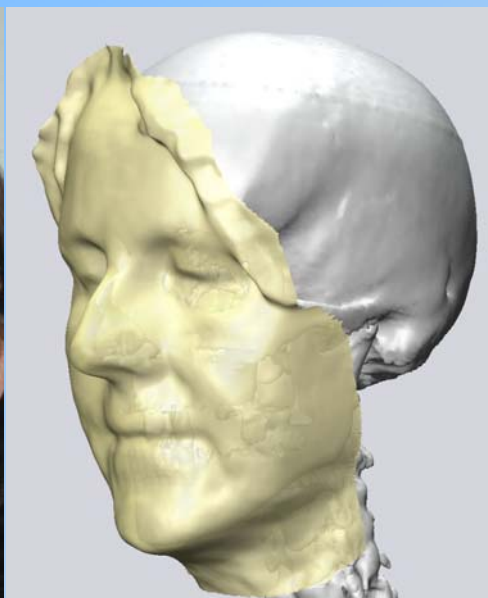
cast
Gerassimov method



3D Modelling with RP Model
H. Stratomeier



comparison forensic reconstruction



Henrike Stratomaier

Digital Photo

3 D holographic
reconstruction

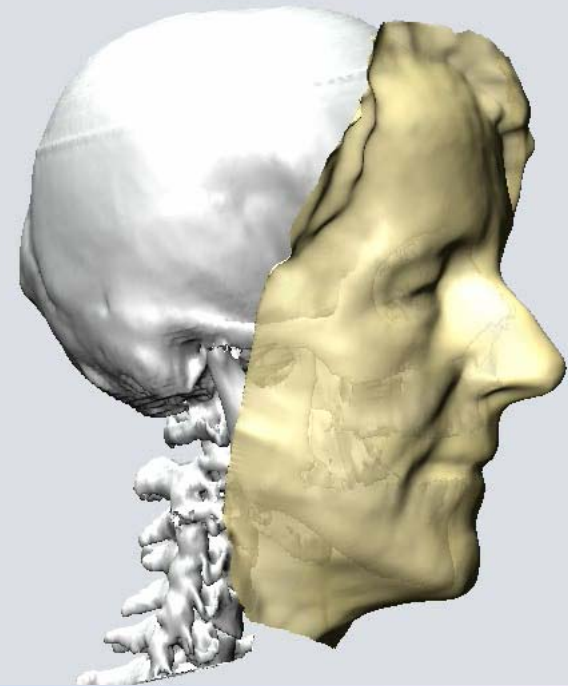
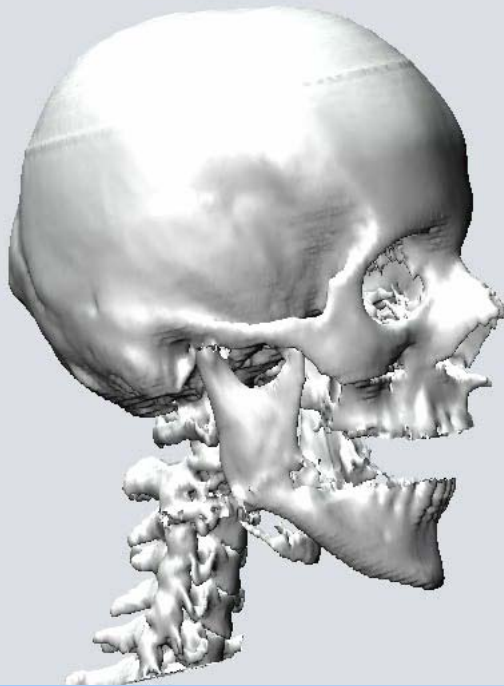
2D reconstruction
BKA

First complete soft tissue data set with high precision:

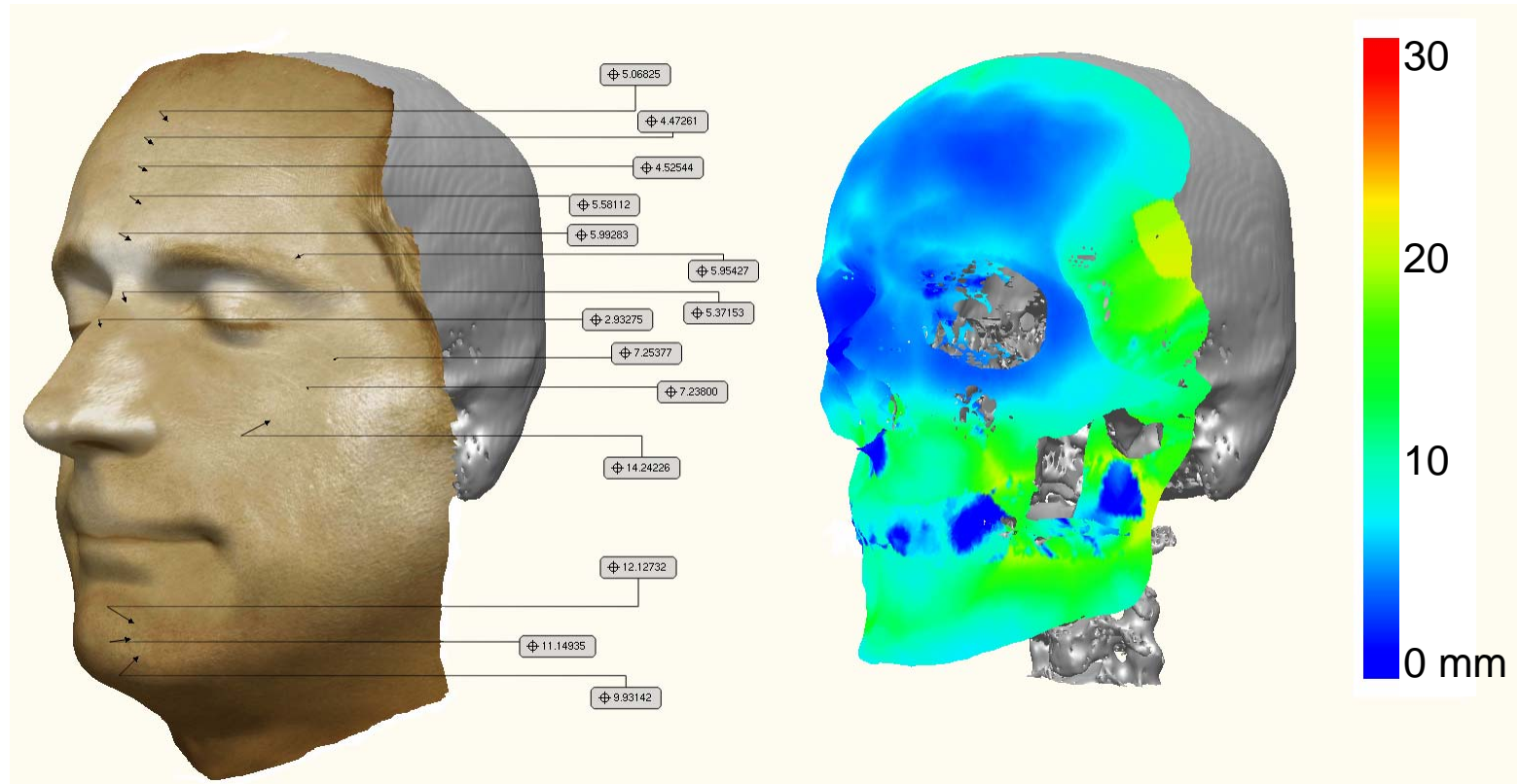
c a e s a r



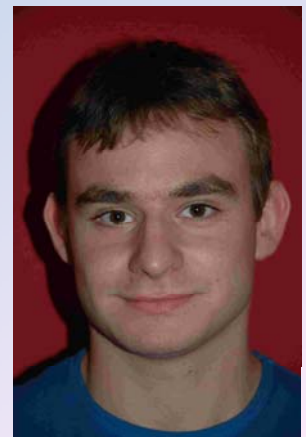
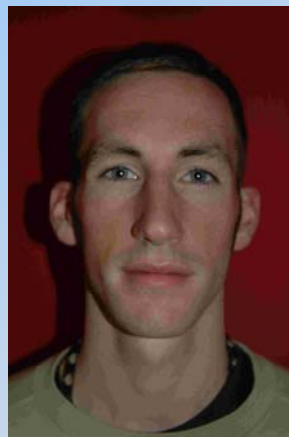
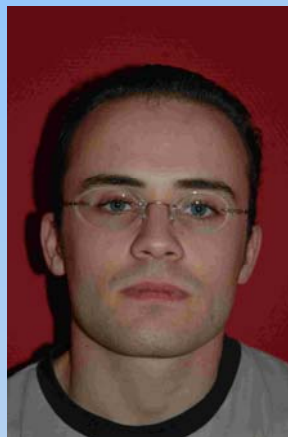
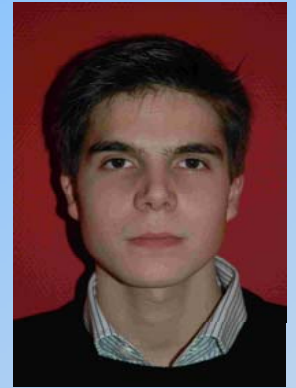
Create 3d database for gender, age, ethnic origine



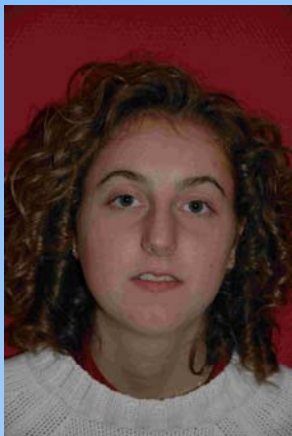
Soft tissue 3d database for gender, age, ethnic origin



**12 male
caucasian
20-25 years**



**12 female
caucasian
20-25 years**



Archaeological application

Neandertal man

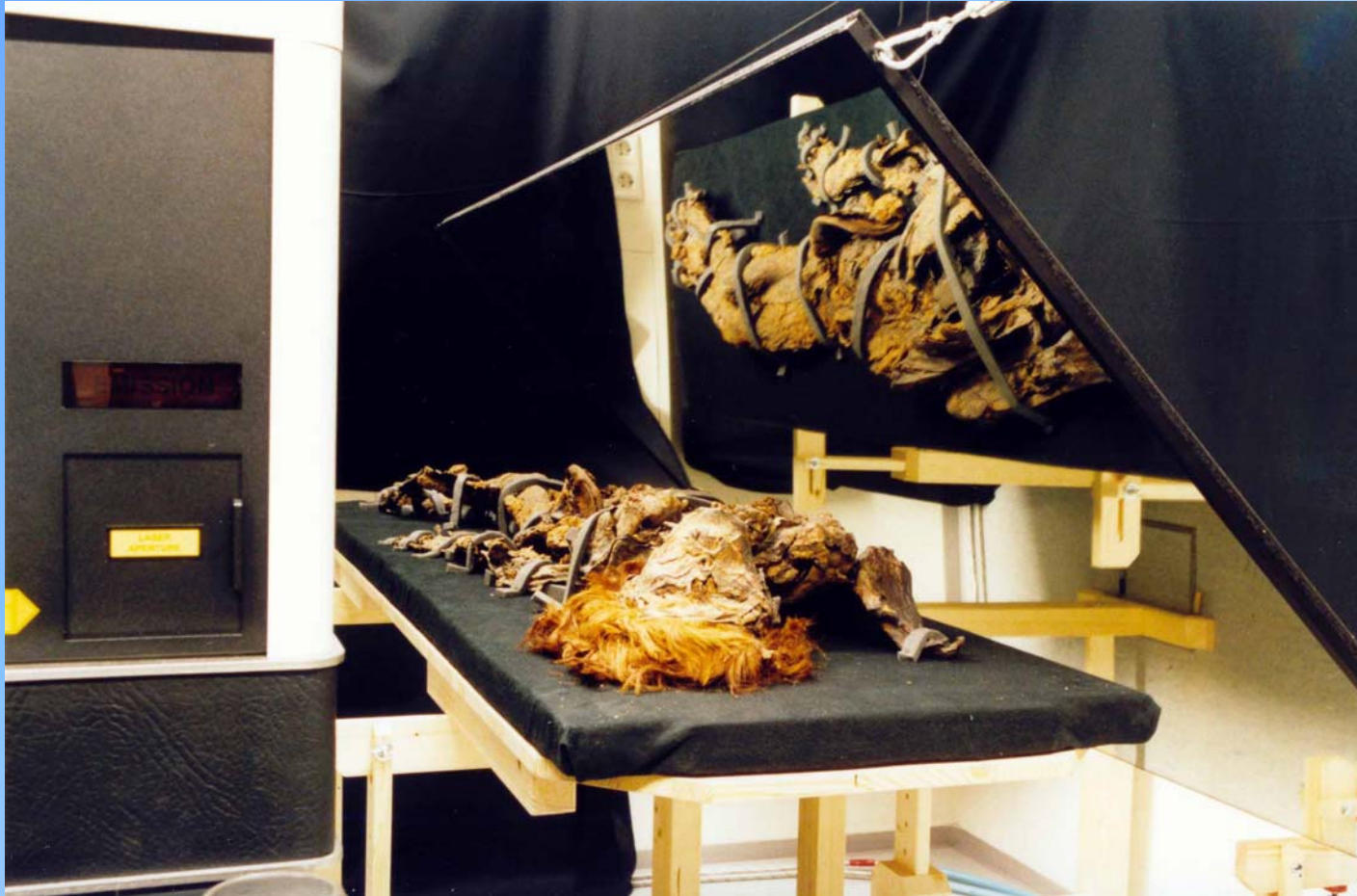
Rheinisches Landes-
museum Bonn



texture very important
no digital photo !!

Our oldest „Patient Husbäke“

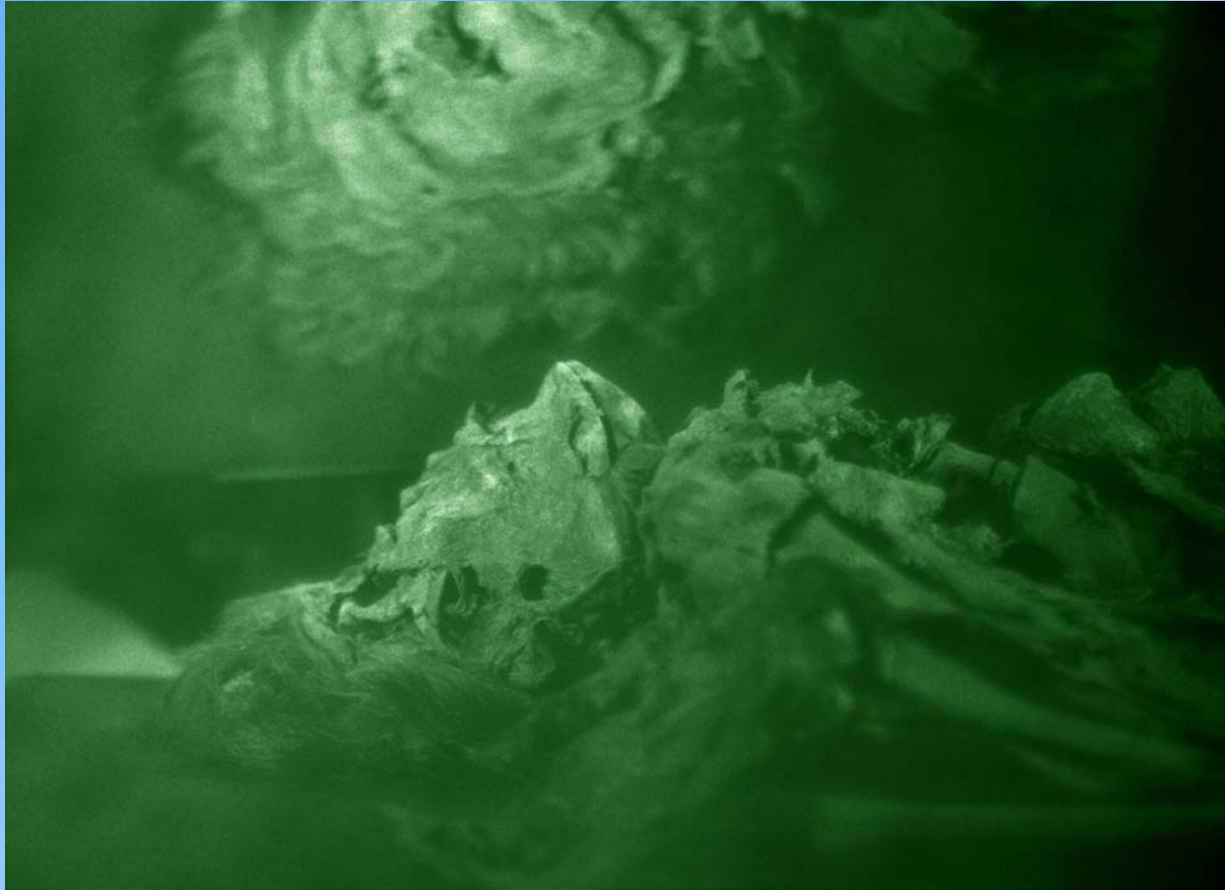
≈ 2000 years old



Kooperation : Landesmuseum für Natur und Mensch Oldenburg

Our oldest „Patient Husbäke“

≈ 2000 years old

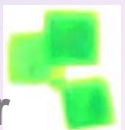
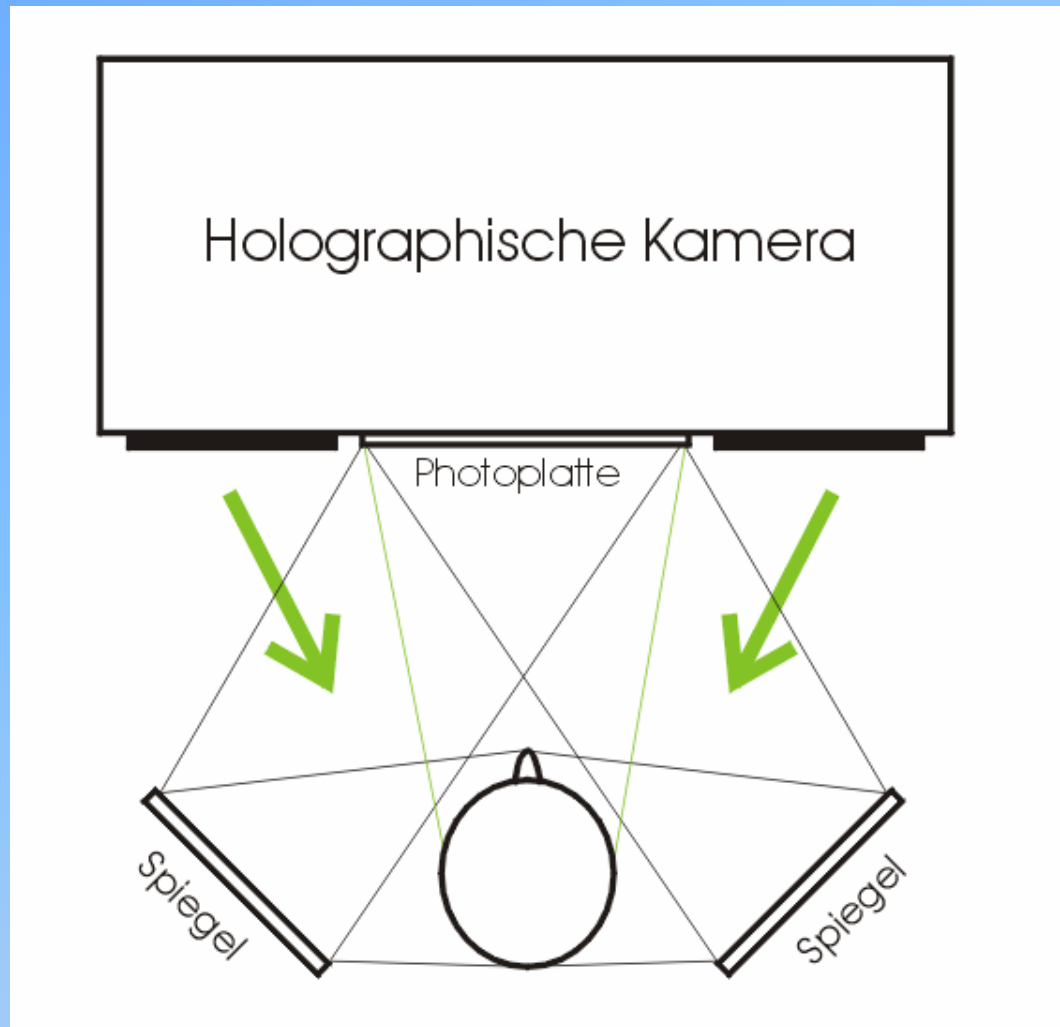


RP Modell
Tille, Seitz



Kooperation : Landesmuseum für Natur und Mensch Oldenburg

270° mirror-setup



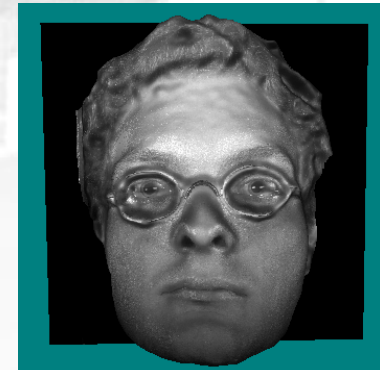
Holographic 2 mirror view in 35 ns (270°)



Mirror Image

Frontal View

simultaneous recording
of different view angles
with 3d reconstruction



Recording of multiple views with one laser pulse



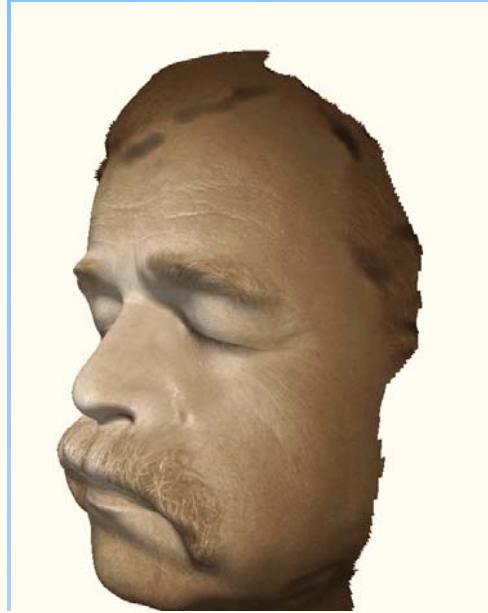
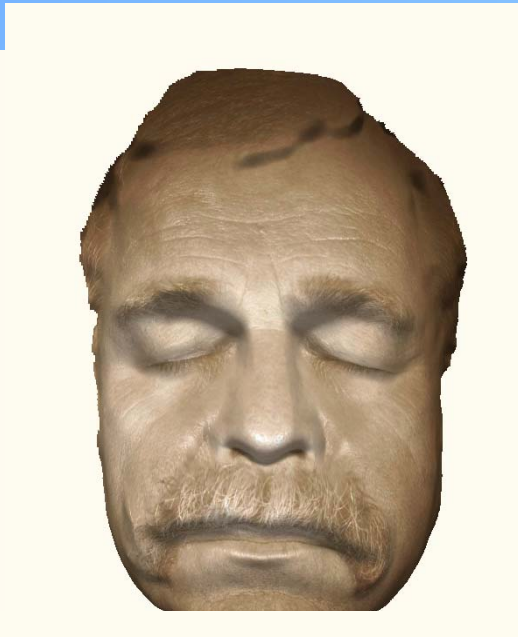


vertical

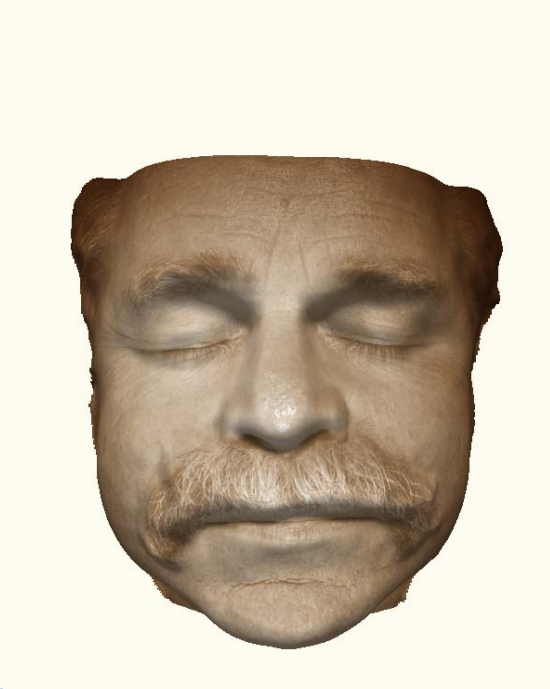


horizontal

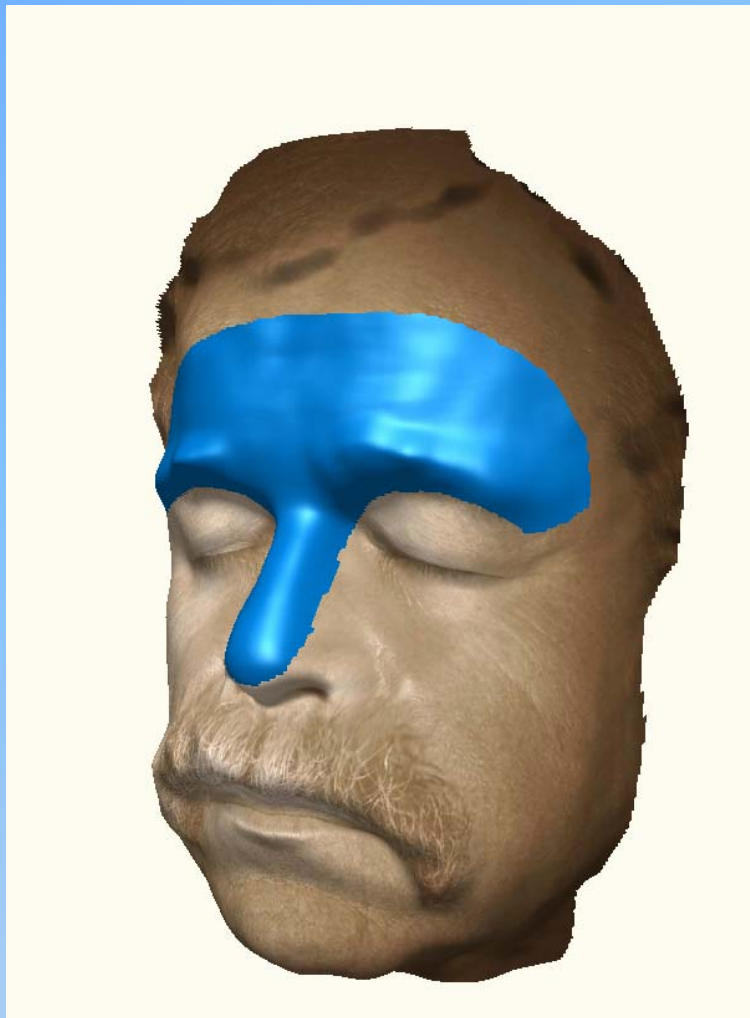
vertical



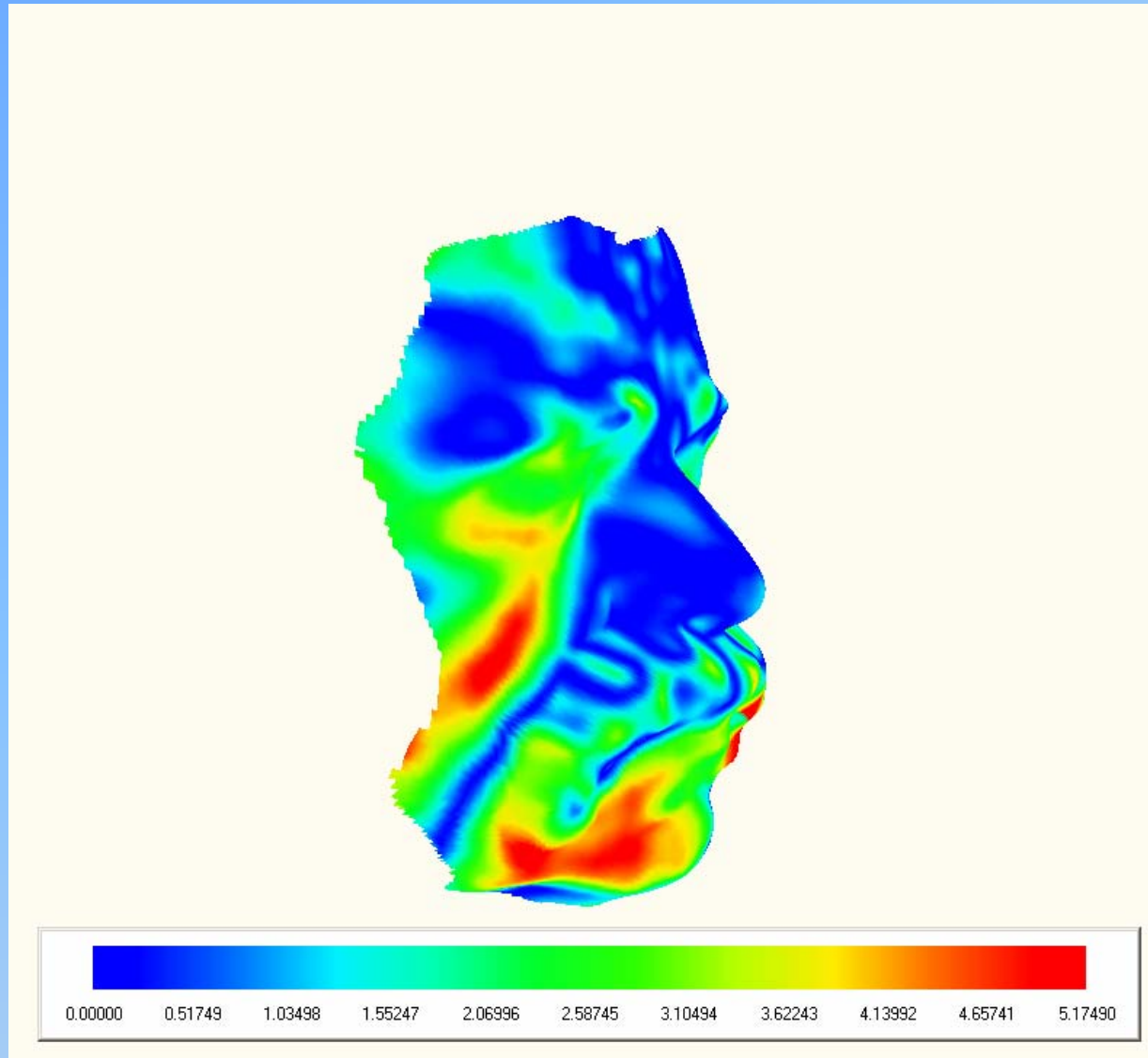
horizontal



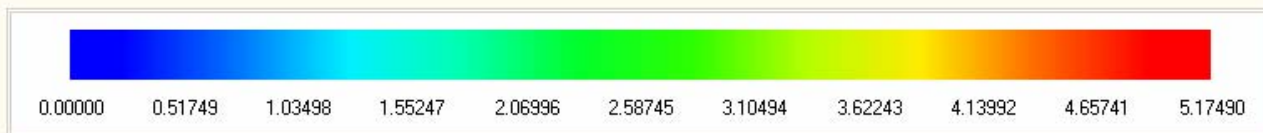
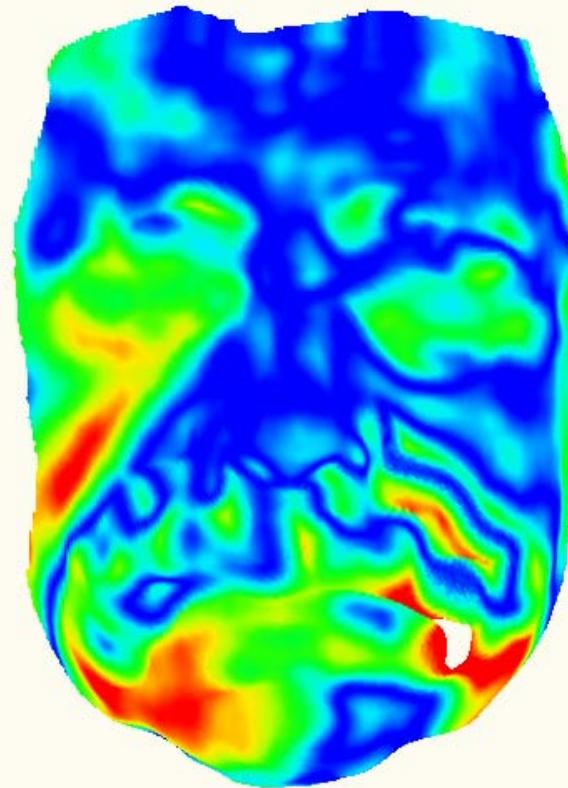
Registrierung der Modelle anhand des blau markierten Bereichs



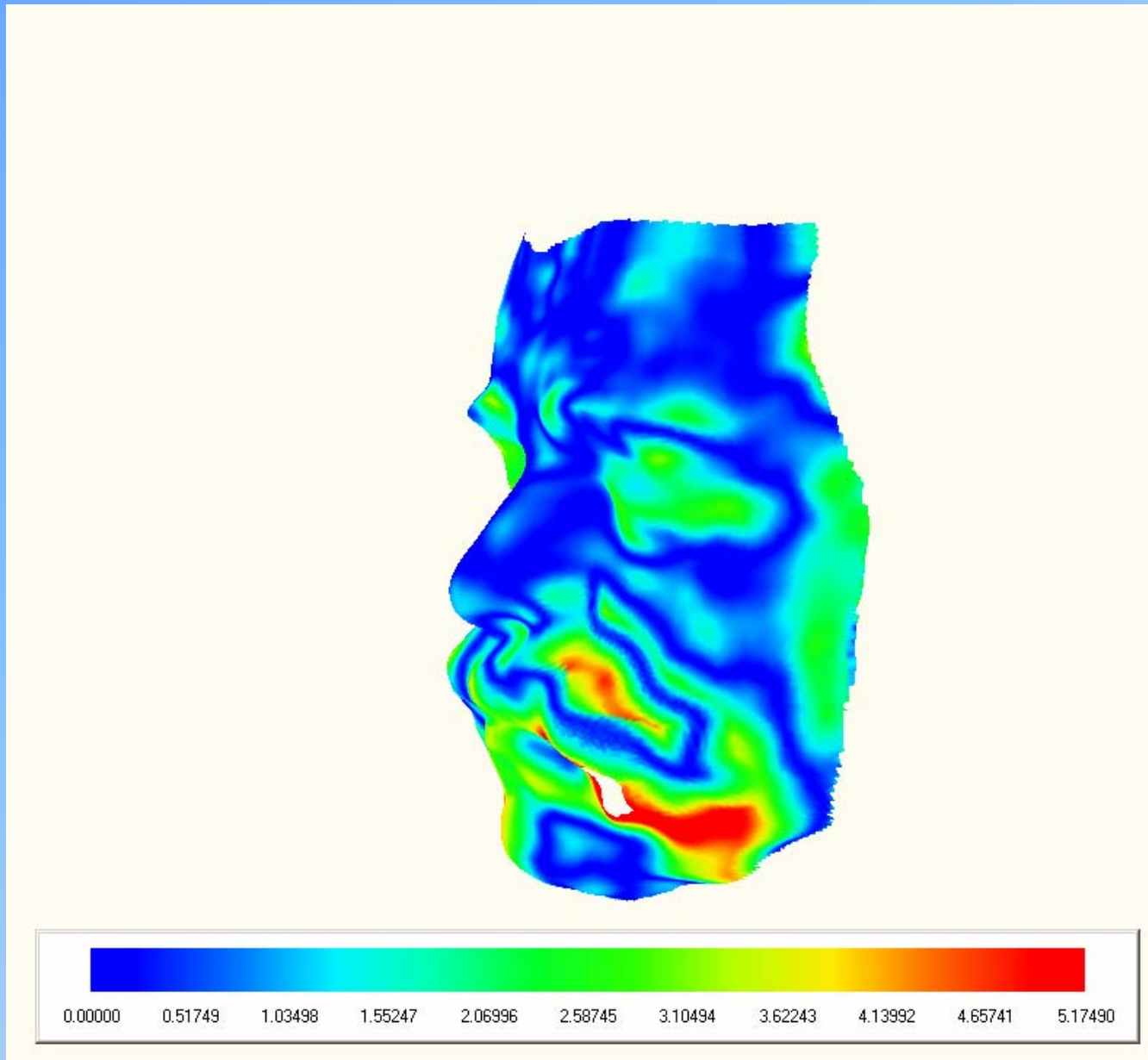
Differenz Farbkodiert (Angaben in mm) / Halbprofil rechts



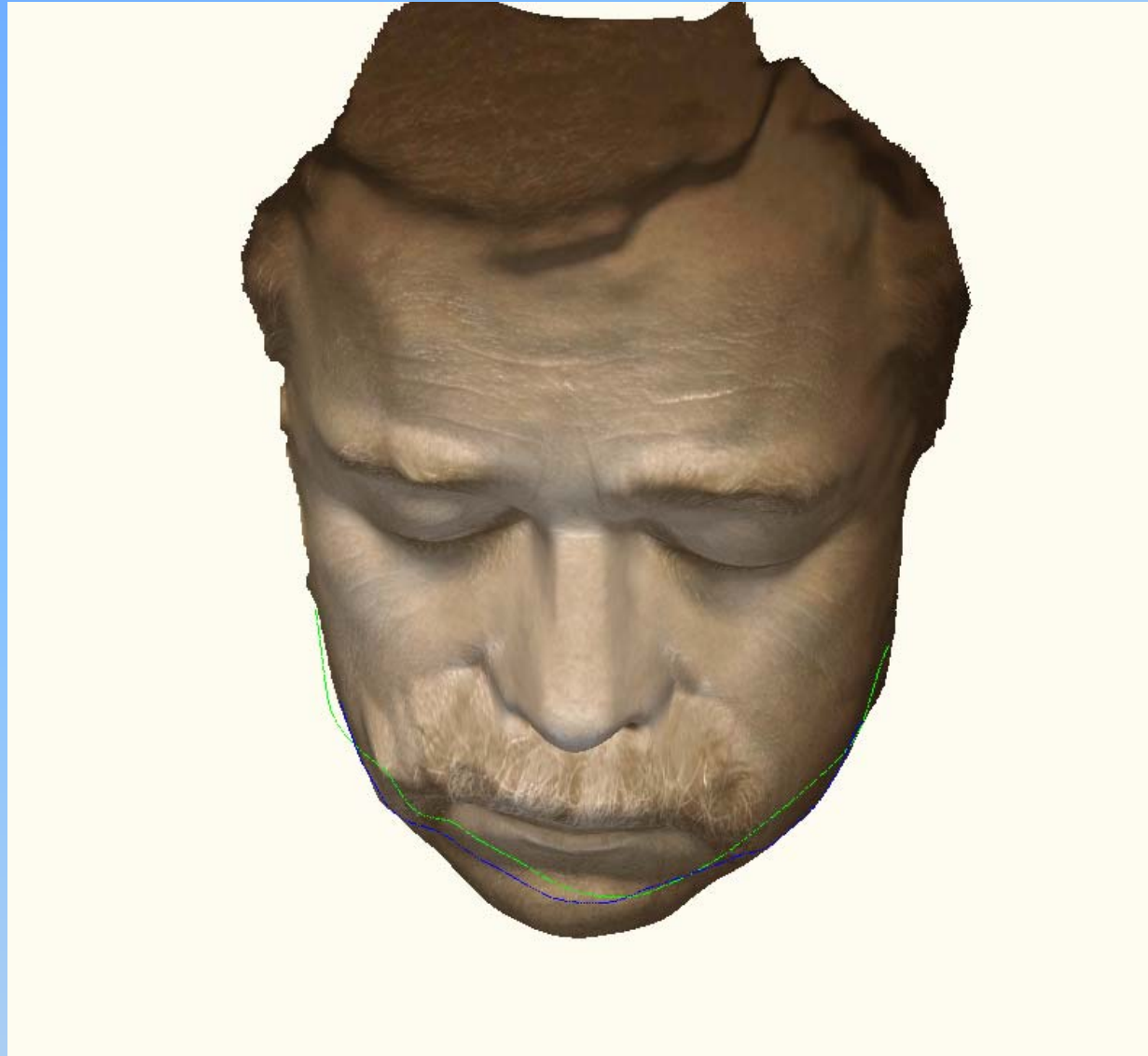
Differenz Farbkodiert (Angaben in mm) / frontal



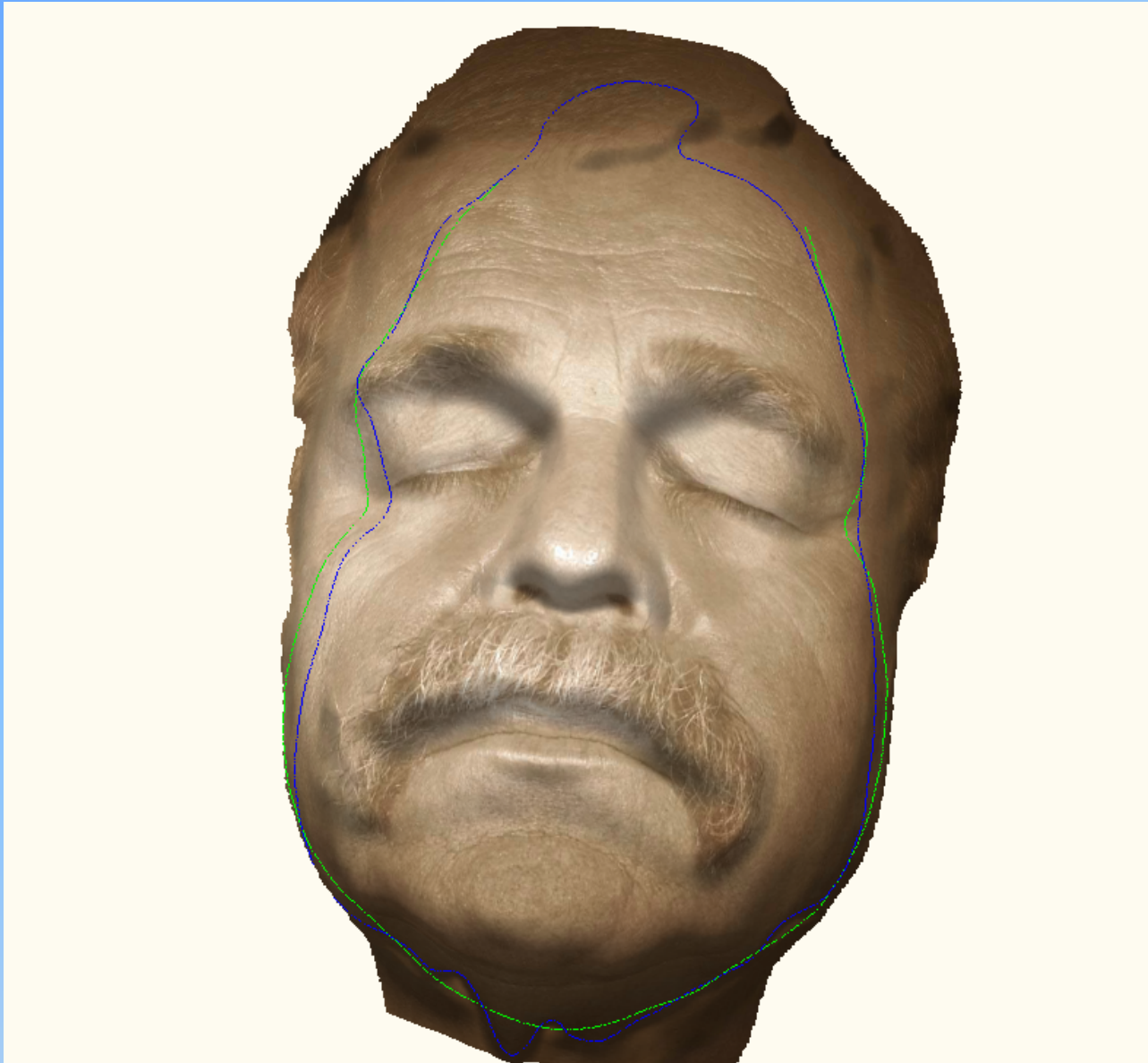
Differenz Farbkodiert (Angaben in mm) / Halbprofil links



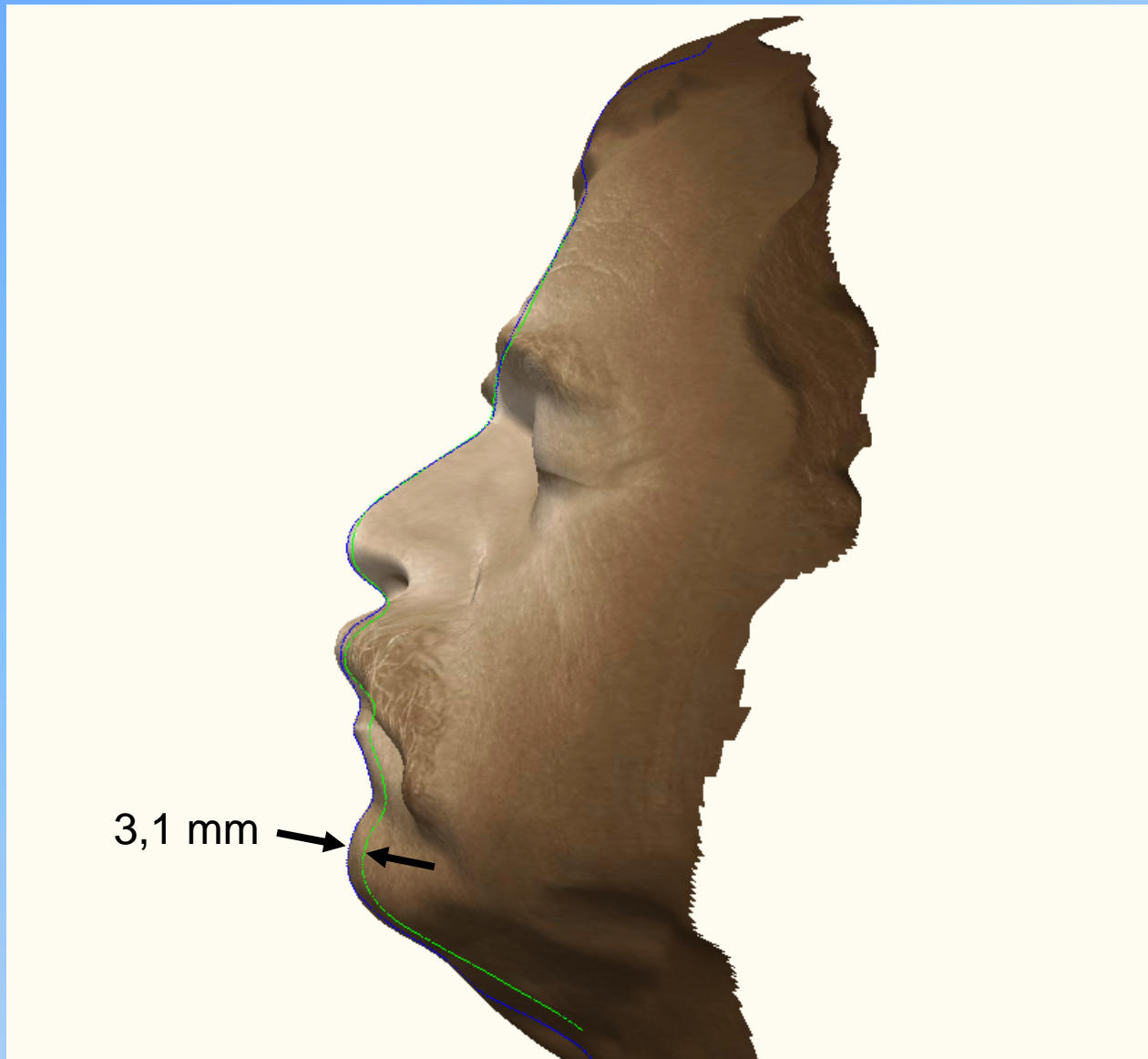
Differenzschnitt (grün – liegend; blau – sitzend)



Differenzschnitt (grün – liegend; blau – sitzend)



Difference (green – horizontal; blue – vertical)



first mobile holographic camera:

c a e s a r



Daylight proof
set up time:
20 minutes
Eye safe
No calibration !!



Summary

Method for fast 3D portrait capturing, which is not influenced by patient's movement.

Method is not limited to medical application, it is also applicable for a wide range of topometric applications.

holographic method superior in:

- time resolution
- Precision, spatial resolution
- completeness of 3D data set
(no holes, interference pattern vs grey values)
- Simultaneous view of 270°

main application

Image guided short pulsed CO₂ laser-osteotomy

Medical facial topometry

Plastic surgery, traumatology

Oral and maxillofacial surgery

Brest implants, face lifting

Biometry (home security)

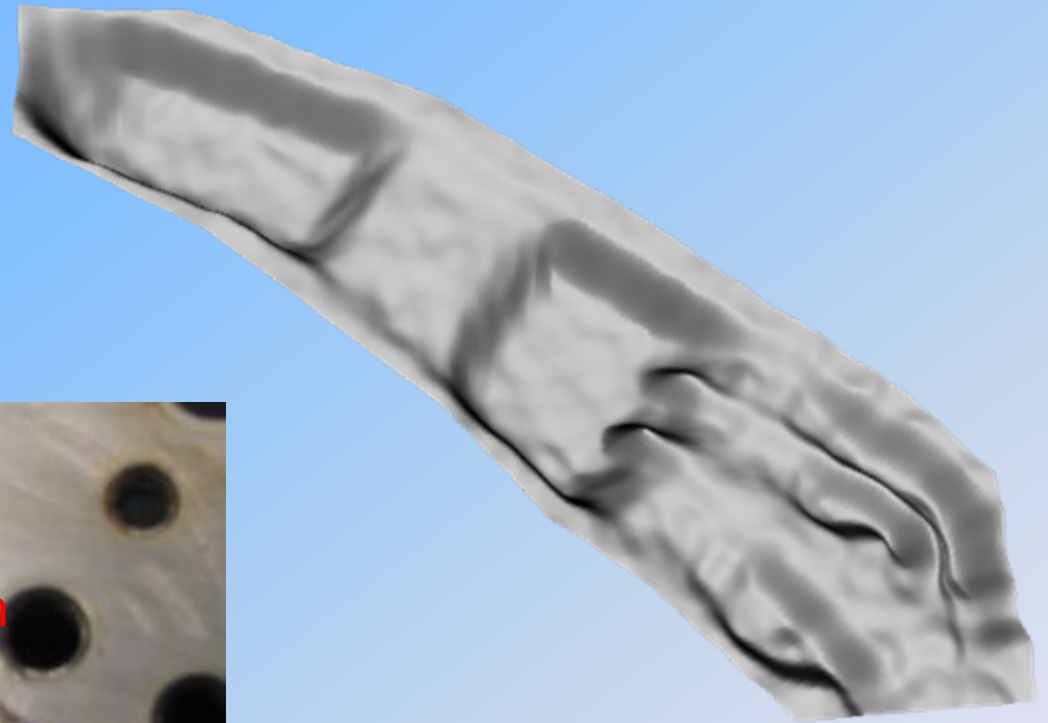
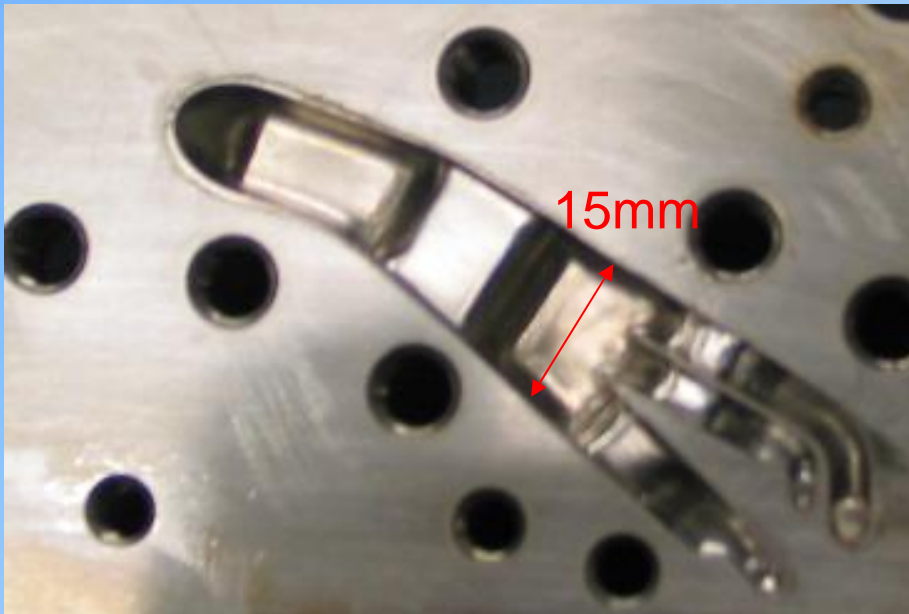
Forensic (crime site)

Archaeology (3d reconstruction of find site)

Technical objects (reflectors)

Strongly reflecting surfaces

pressure casting



Axial resolution:
ca. 150 μm

Laser ablation in medicine

Hard tissue processing with short pulsed CO₂ laser pulses

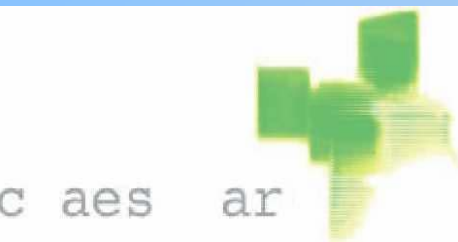


Dr. Michail Ivanenko Martin Werner Manfred Klasing,



Former members: Dipl. Phys. Antje Rätzer-Scheibe

Dr. Said Afilal



**Former members: Thomas Mitra, Tatiana Brocks,
Rene Michels, H. Handreck, O. Kuhne, J. Göthel**

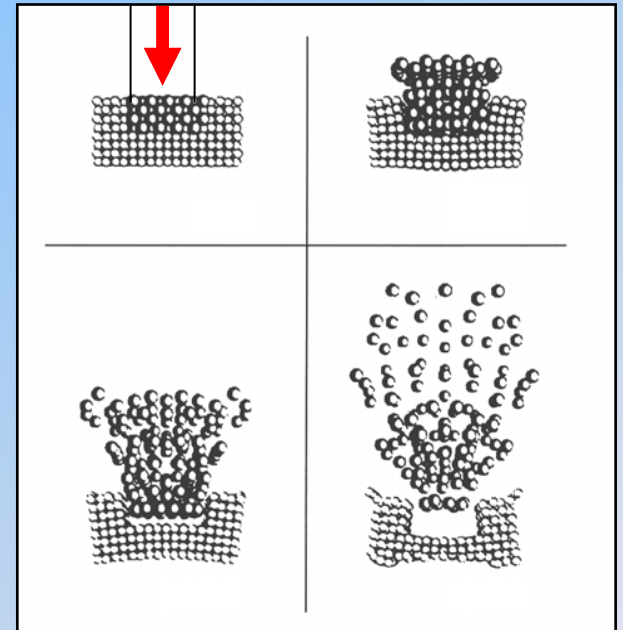


Lasers in Medicine



mode of action

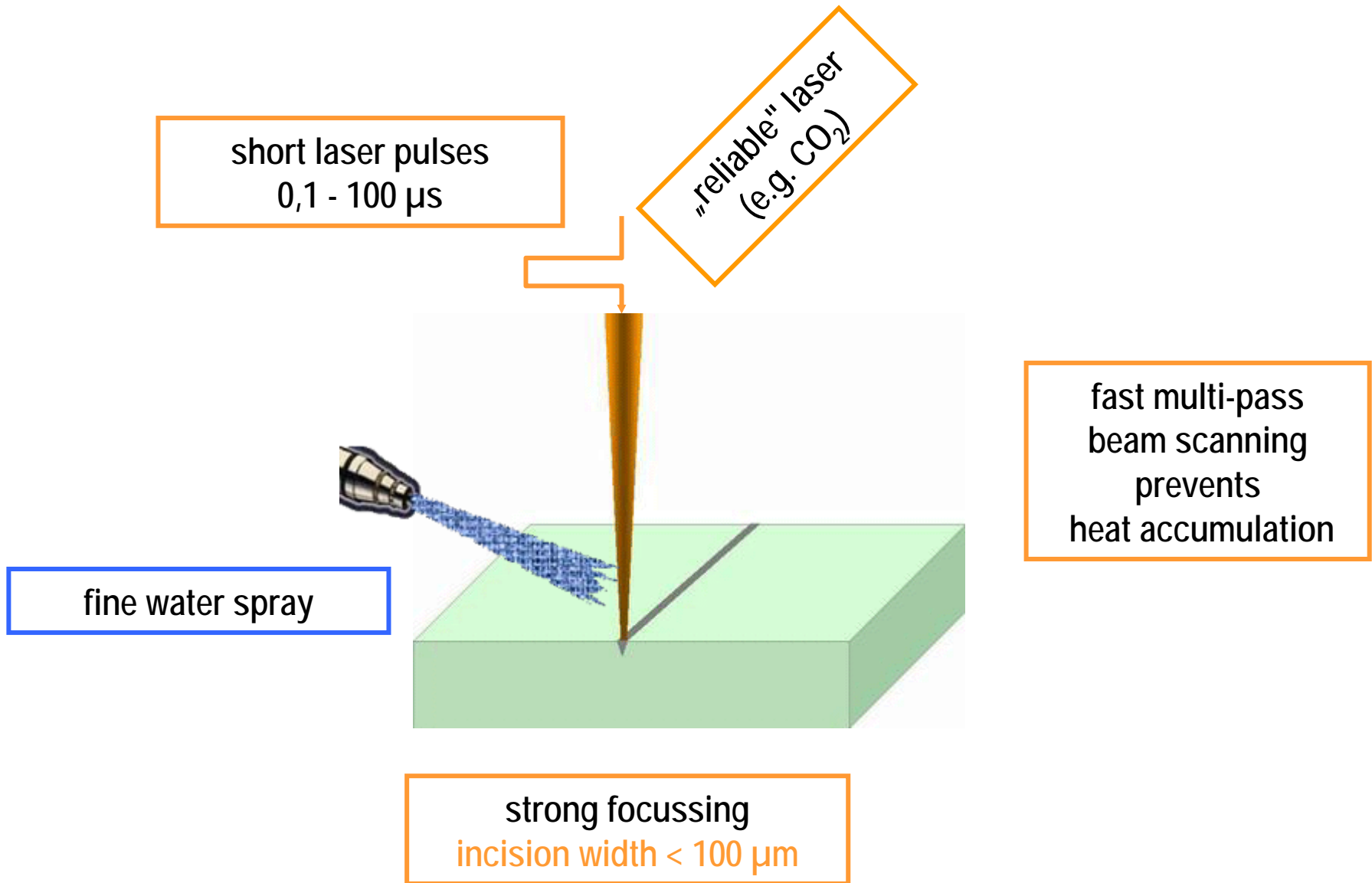
- IR photo ablation
- thermo-mechanical ablation mechanism through high absorption of water and hydroxyapatite
- very fast energy deposition
- micro-explosion by sudden vaporization of water



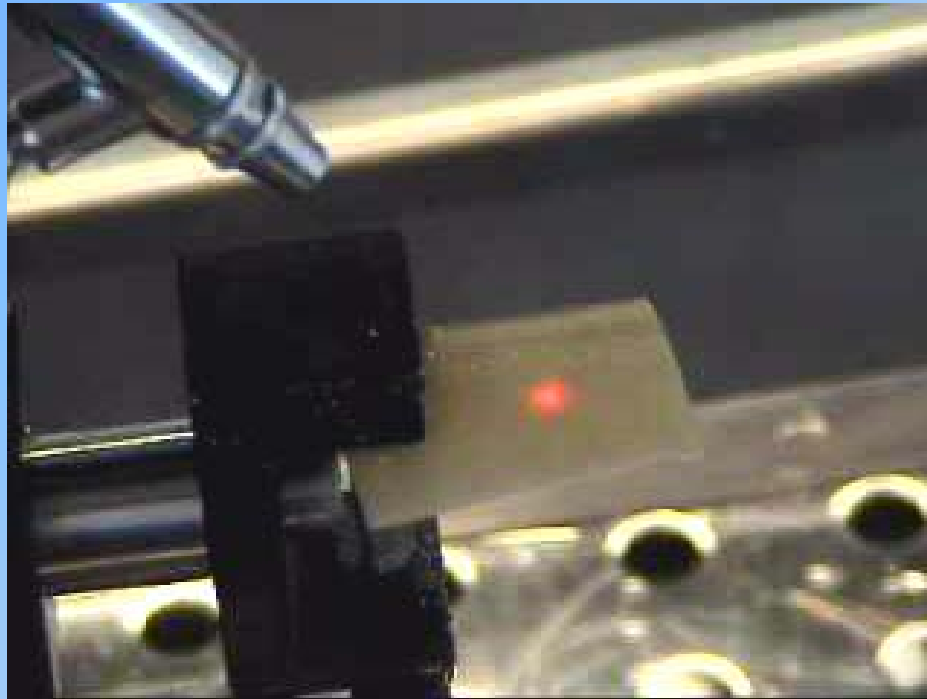
Use in medicine

- dentistry
- Ophthalmology
- **Laser Osteotomy**
- Dermatology

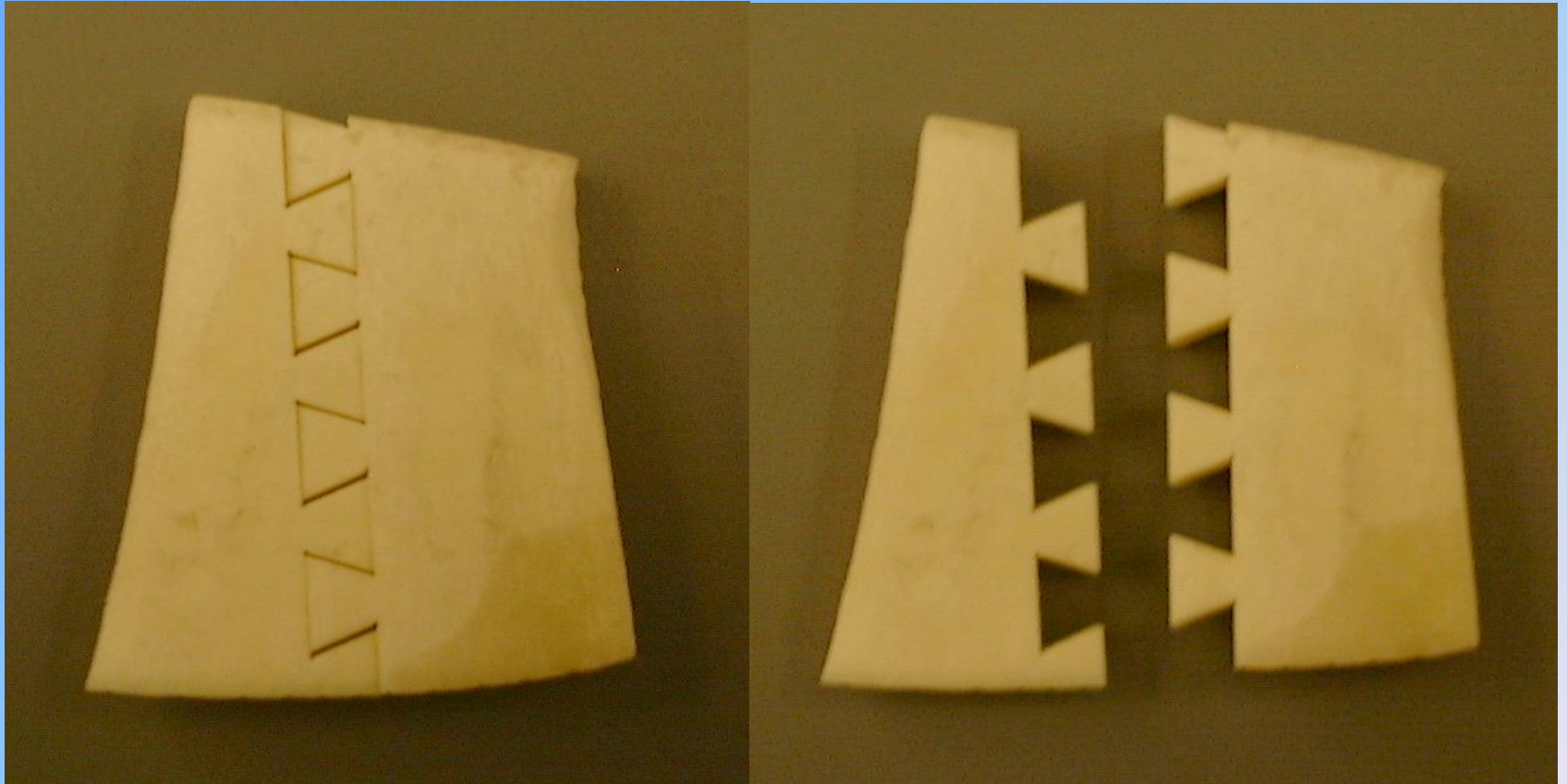
Thermo-Mechanical Ablation Process



dovetail – bovine bone – 25 seconds



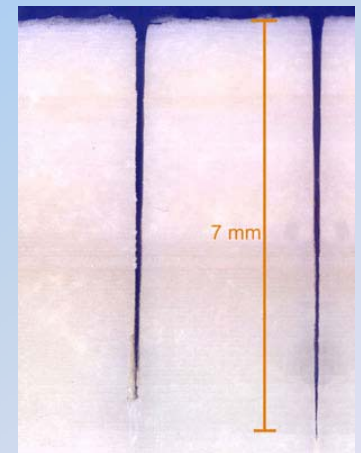
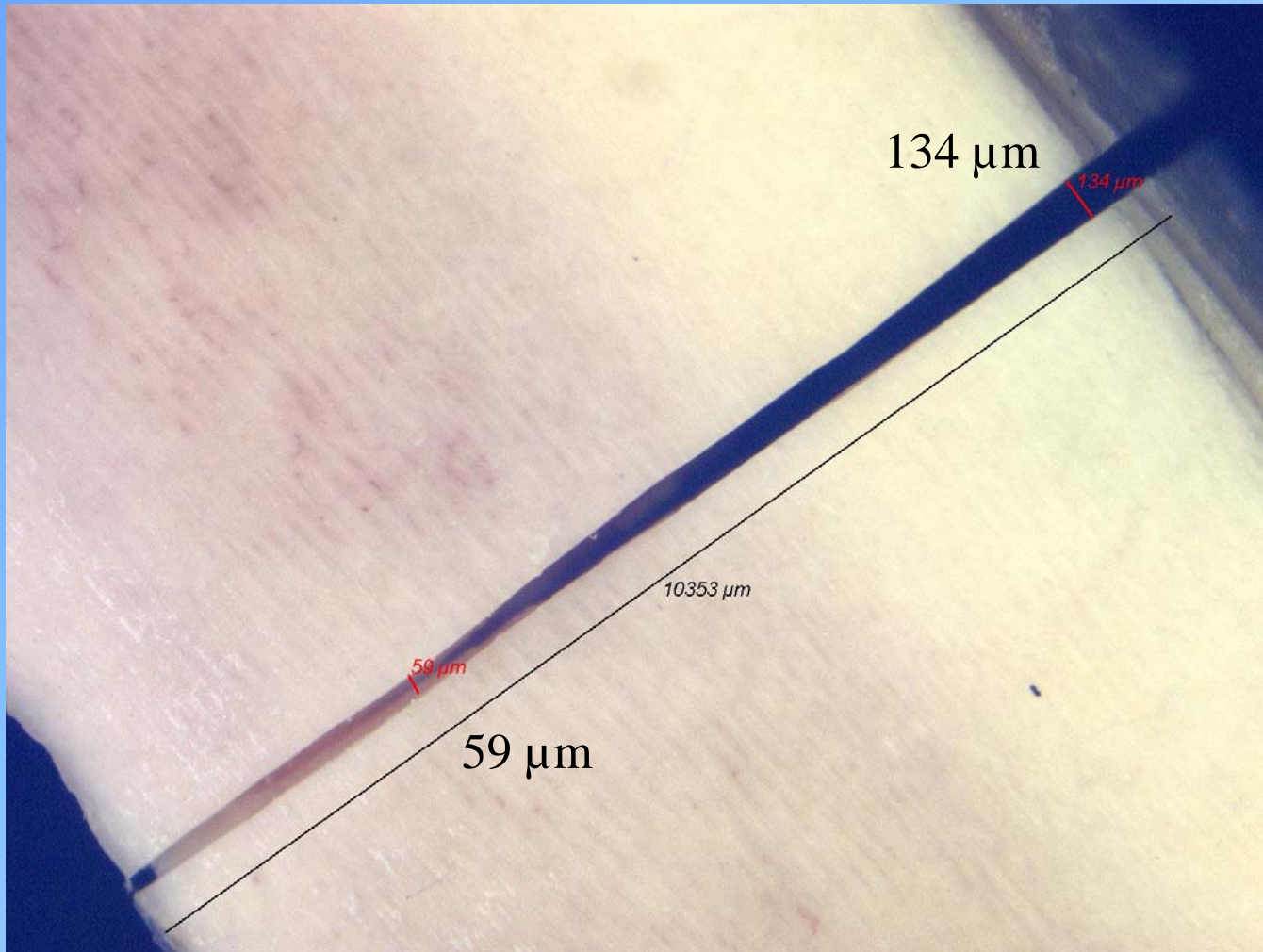
Free cut geometry with 3D Scanner and short pulsed CO₂ Laser



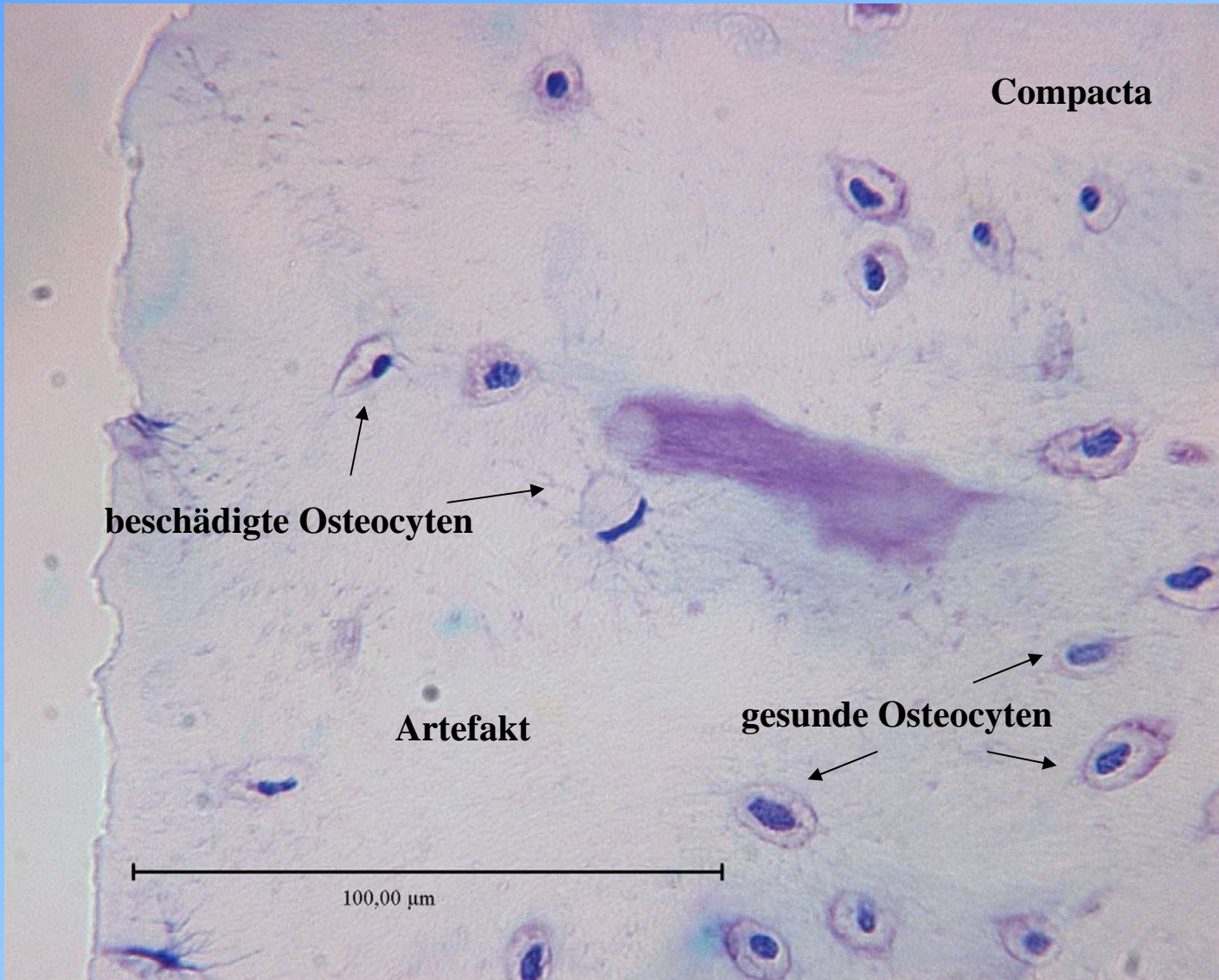
Free cut geometry with 3D Scanner and short pulsed CO₂ Laser



bone cut with short pulsed CO₂ Laser



Diamond Saw



40x Vergr.
Schweinerippe
Richardson-
Färbung

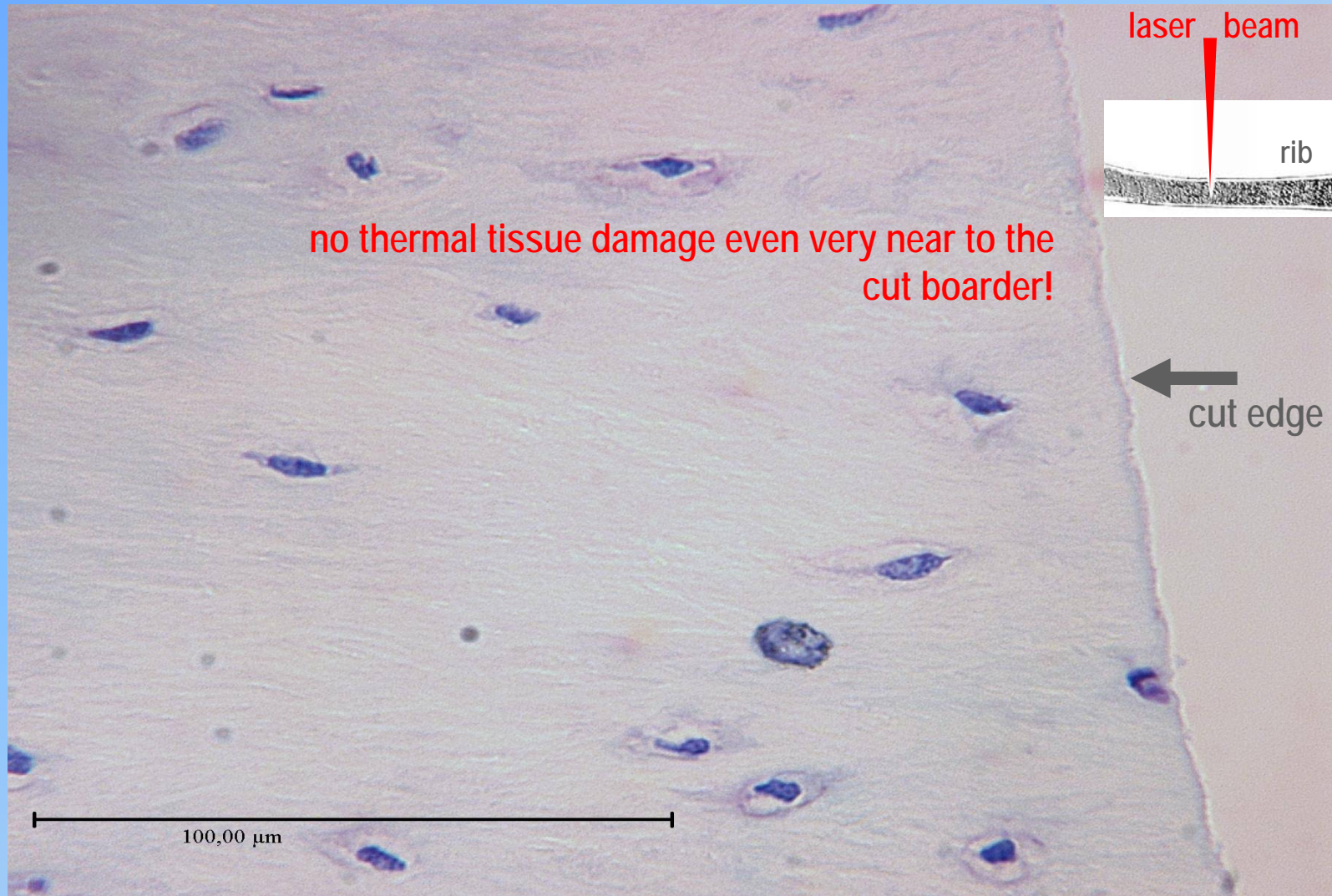
Diamantsägeblatt
185 m/s

100 µm
Schädigungszone

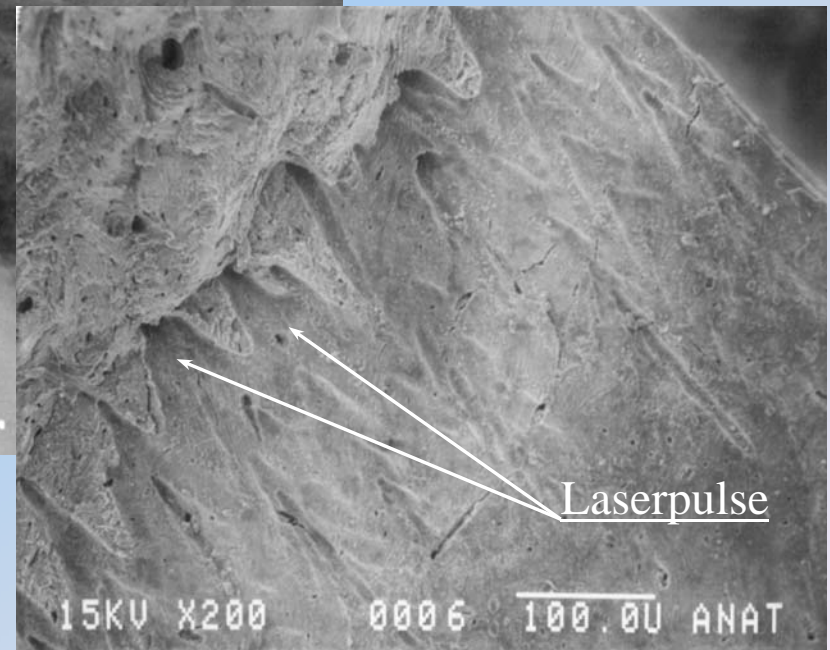
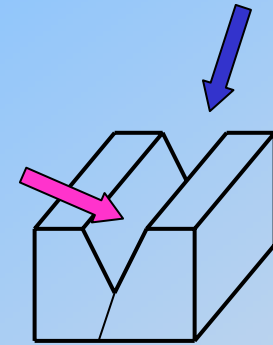
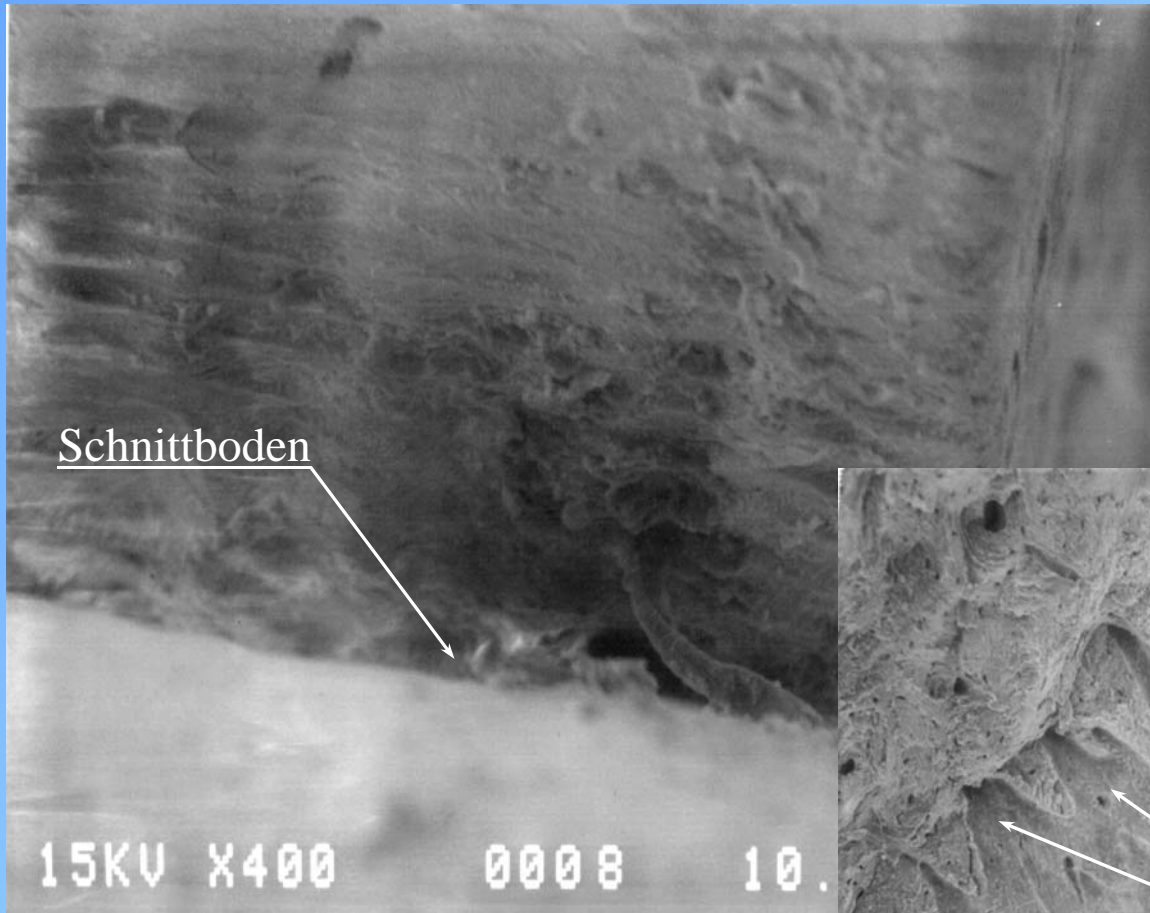
Starke Variation

histologic slice over an *in vitro* cut in a pig rib compacta with a TEA CO₂ laser

9.57 μm , 40% energy in a 45-ns spike, 60% energy in a 1- μs tail,
elliptical focus 0.64 x 2.2 mm, $\Phi = 3.7 \text{ J/cm}^2/\text{pulse}$, $f = 40 \text{ Hz}$,
Richardson staining



REM-Aufnahmen CO₂-Laser (gütegeschaltet)





laser mirror arm

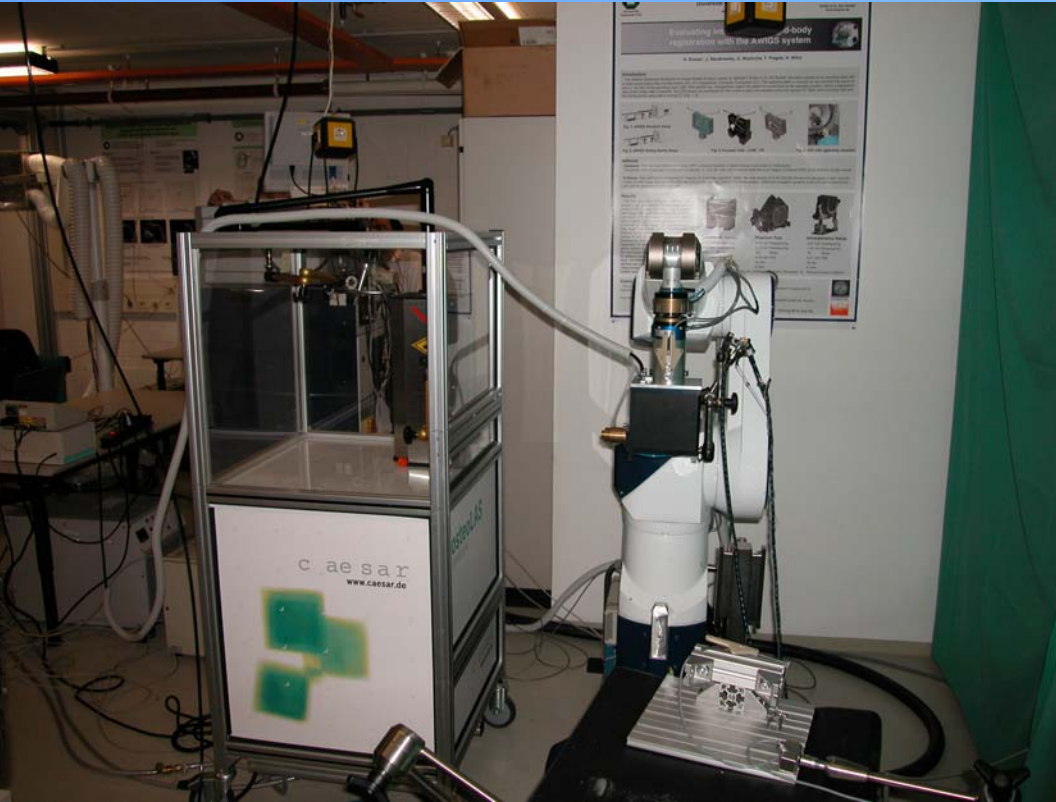
laser scanner

osteolas
[prototype]

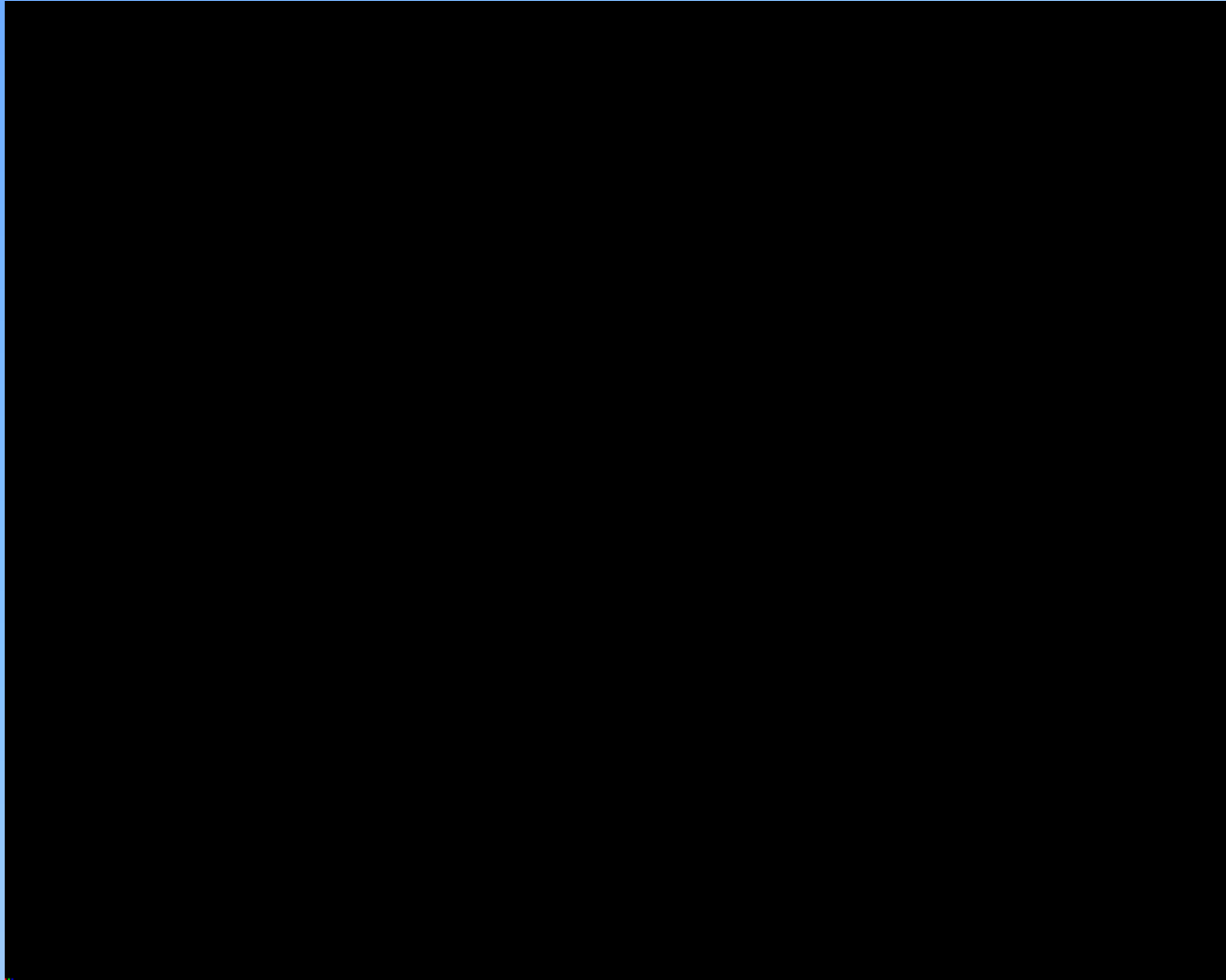
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177

Robot guided laser osteotomy

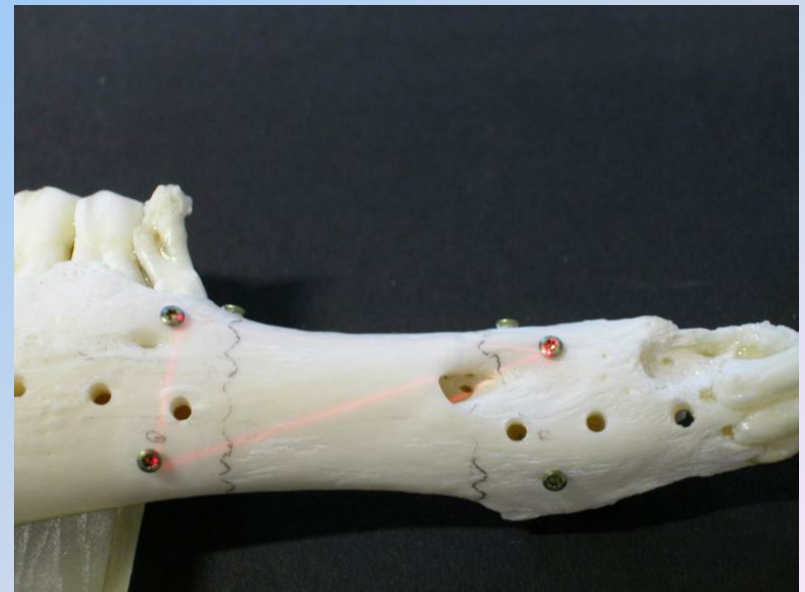
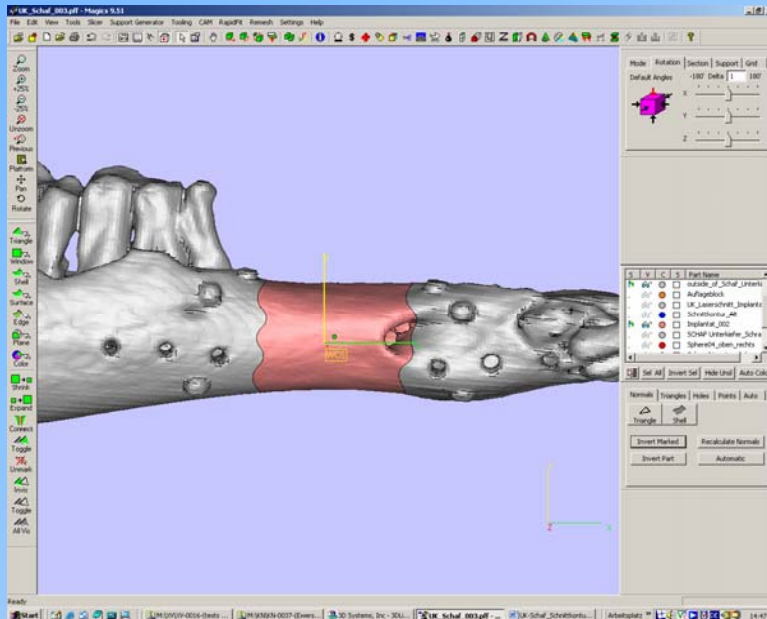


roboter laser osteotomy



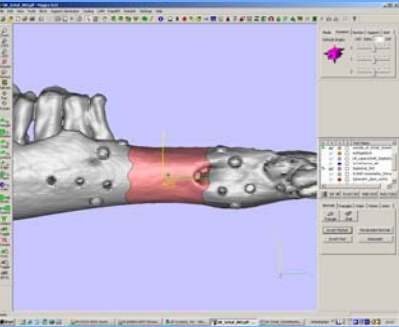
Preliminary Trials – Sheep Jaw Bone with CT data based Laser Navigation

navigation by laser
controlled positioning of
marker points according to
CT data



virtual planning and navigation

3-D planning of the operation on the basis of patient CT data and Individual rapid manufacturing of a bioresorbable implant



Laser navigation

Laser osteotomy



Application in medicine:

Neuro surgery (Trepanation without metal abrasion) NMR pictures!

Thorax surgery (Sternum)

Maxillo facial surgery

ENT surgery

Plastic surgery

Orthopaedy (Implants)

Application in material processing:

heat-sensitive synthetic material, rubber (tires), wood etc.

Thank you for your attention

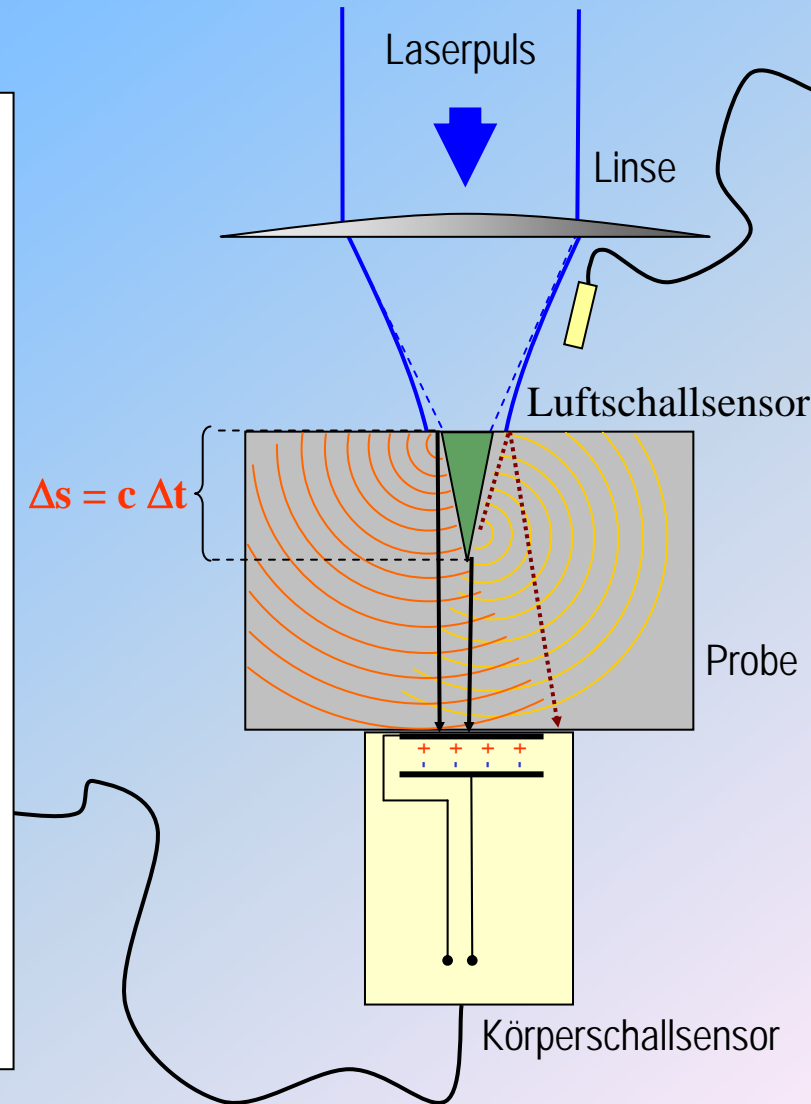
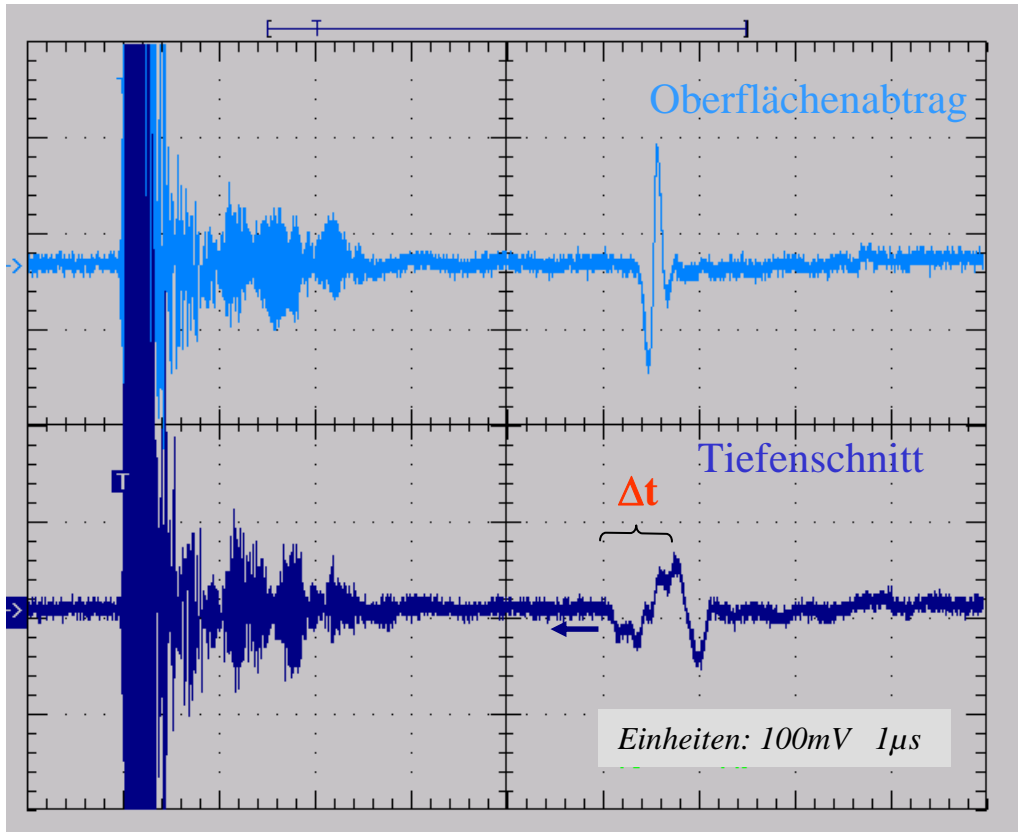
hering@uni-duesseldorf.de

hering@caesar.de

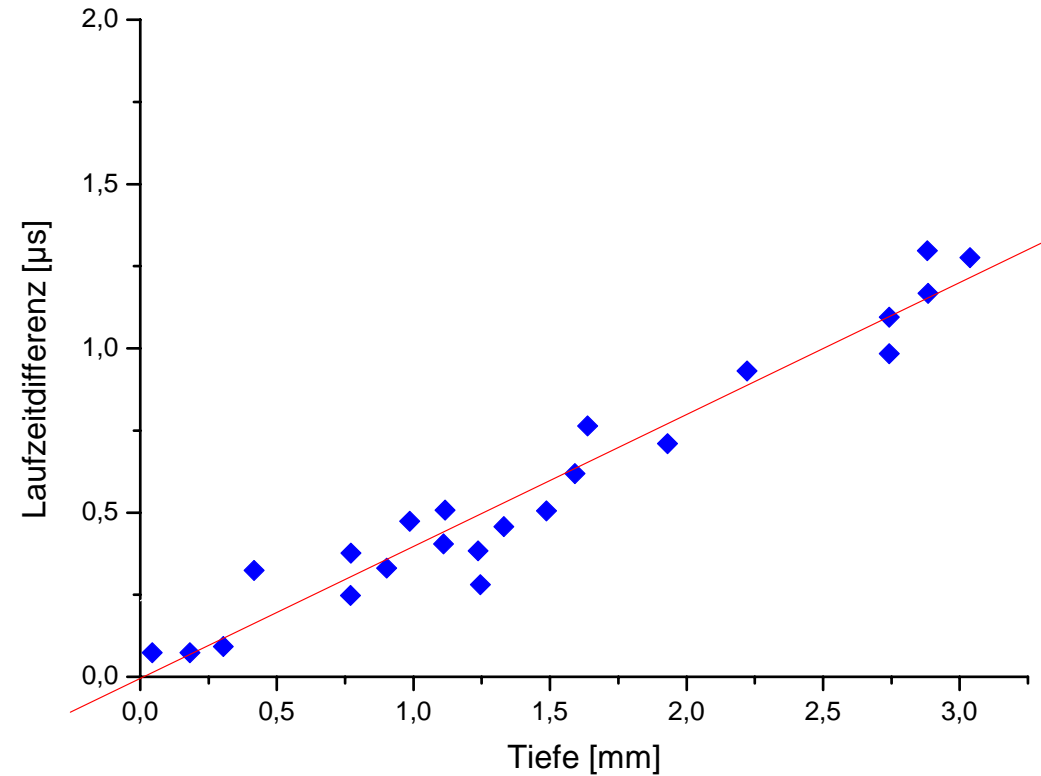
www.caesar.de

Akustisches Signal bei Laserablation

Körperschallsignal



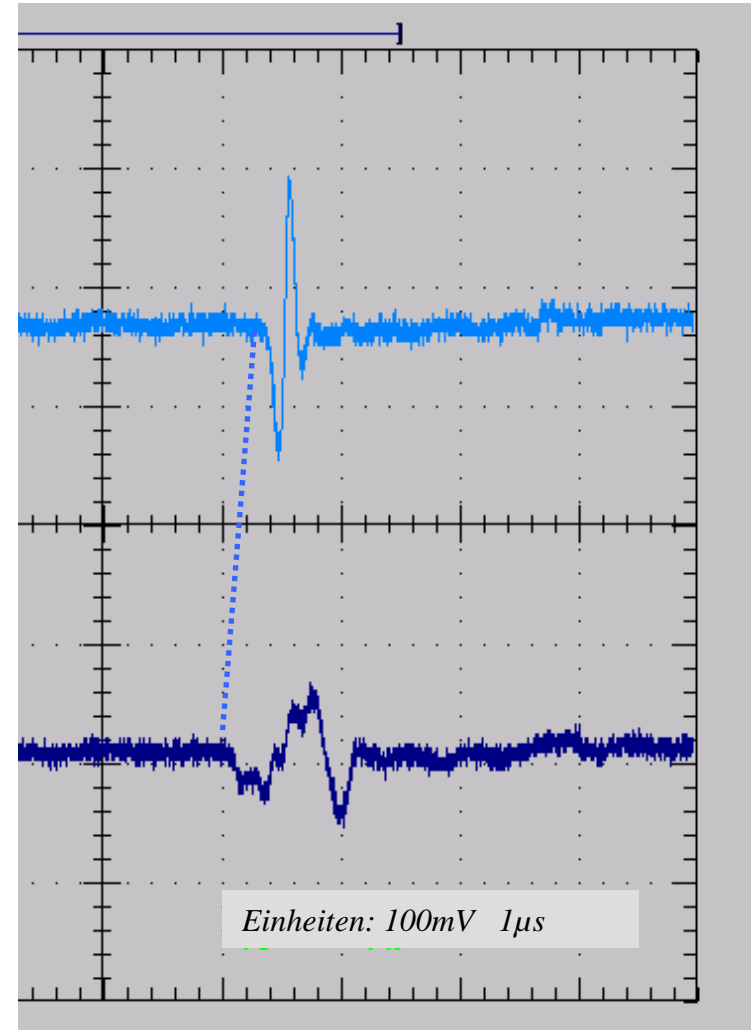
Bestimmung Tiefe und Schallgeschwindigkeit

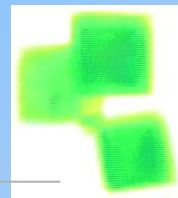


Schallgeschwindigkeit:

$2350,9 \pm 125,09$ m/sec (Exp.)

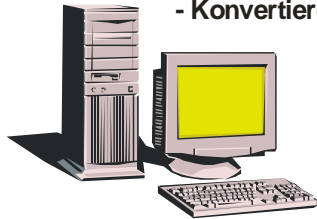
2240 m/sec (Lit.)



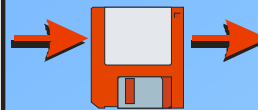


CAD-Workstation

- Aufbereitung der 3D-Daten
- Überprüfen
 - Stützengenerierung
 - Konvertieren (Slicen)



(S)CLI-File



Prozeßrechner

- Steuerung des Prozesses
- Echtzeit-Scannersteuerung
 - Echtzeit-Modulatorsteuerung
 - Recoating



Stereolithographie-Maschine

