New X-ray optics for biomedical diagnostics

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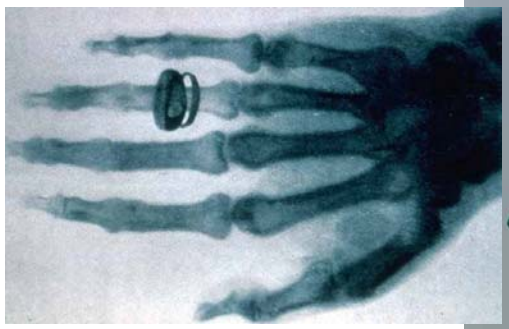


EU Project X-ray BIOIMAGING (ref. No. 241402)

talk is given in the name of Franz Pfeiffer as one of the collaborating institute in this project

ERC starting grant – condensed matter physics programm *FP7-IDEAS*

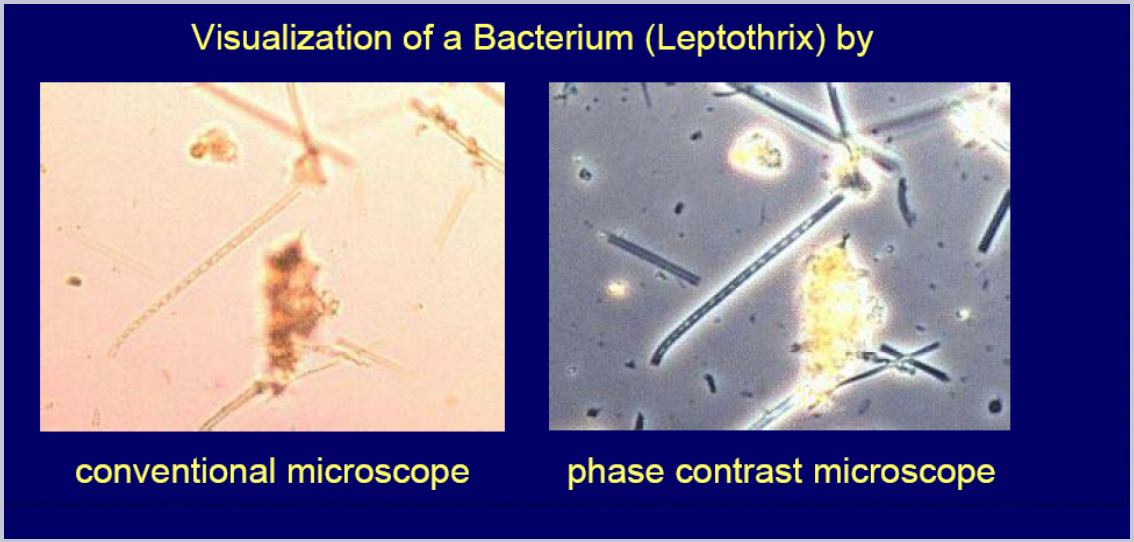
X-ray phase-contrast imaging for biomedical applications

resp. scientist: ***Prof. Franz Pfeiffer*** *organisaton:* ***Technical University Munich, physics dep. (E17)***
Chair for Biomedical Physics

goals

- evaluation of the potential of phase-contrast CT for biomedical diagnostics
- development of a **first pre-clinical small-animal phase-contrast** X-ray CT system
- improving the theoretical understanding of the physical principles of grating-based phase-contrast imaging and tomography

The Physics Behind: Phase Contrast Technology for X-Rays

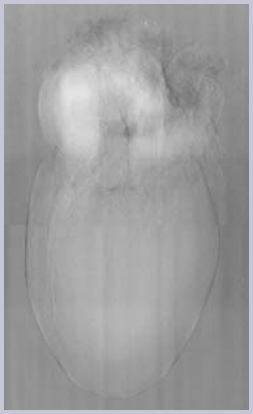


comparable to what is known in visible light

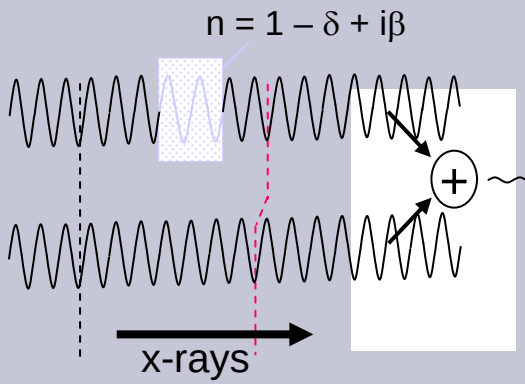
phase contrast imaging/microscopy
(F. Zernike 1934)

in case of 50 µm tissue: absorption is only 0,2 % - phase shift 180°

strong absorbing material is imaged



absorption contrast



rat heart

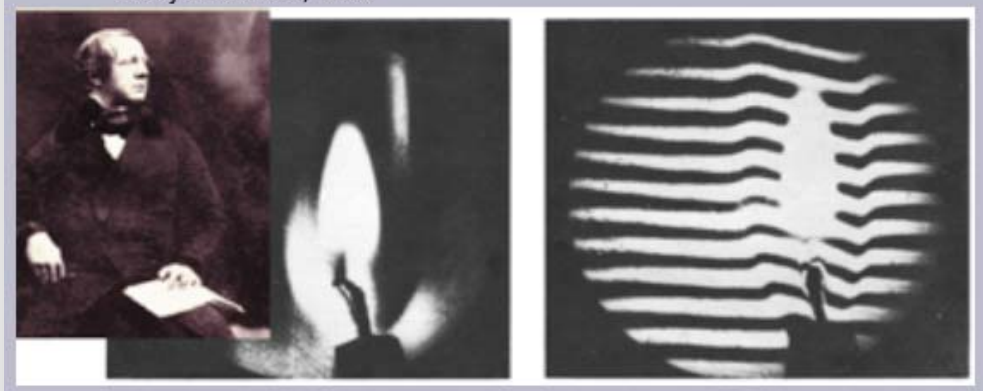
phase contrast

➔ **much higher contrast**
➔ **less dose required**

(images provided by T. Weitkamp, ESRF)

Making the Interferogram Visible by the Talbot Effect

Henry Fox Talbot, 1836

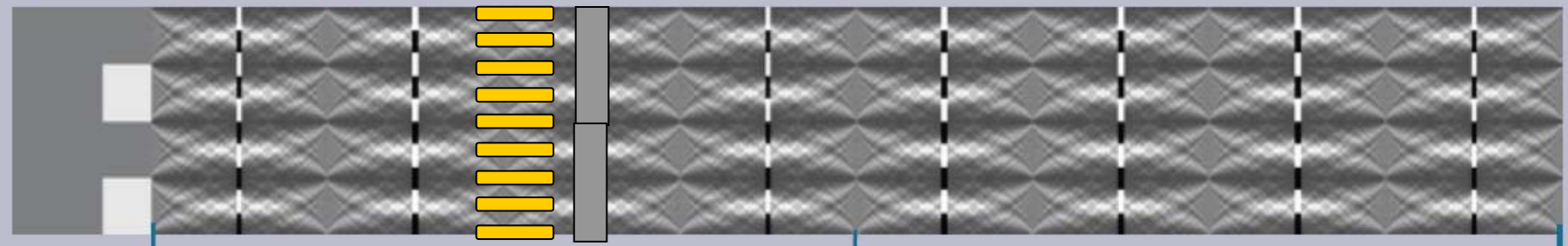


A. W. Lohmann and D. E. Silva, *An interferometer based on the Talbot effect*,
Optics communication 2, 413-415, (1971).

Talbot distances

$$d = n\frac{p^2}{8\lambda}$$

phase grating $\Delta\phi = 1.0\ \pi$, period p_1



phase grating

absorption grating

detector

0

p_1^2/λ

$2p_1^2/\lambda$

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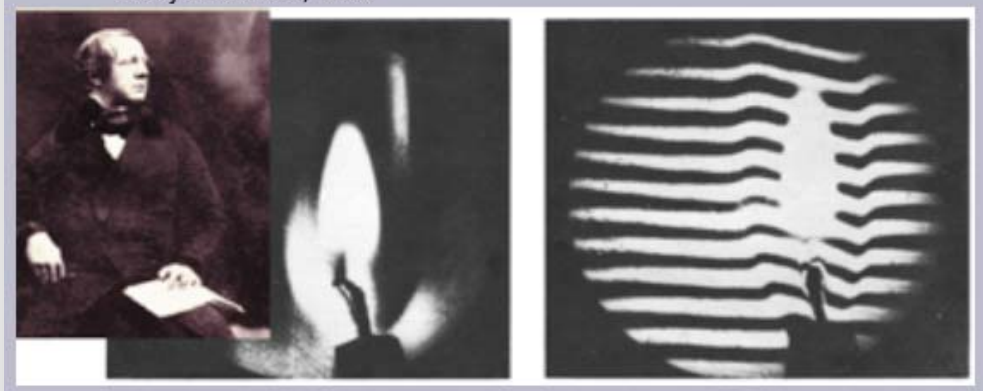

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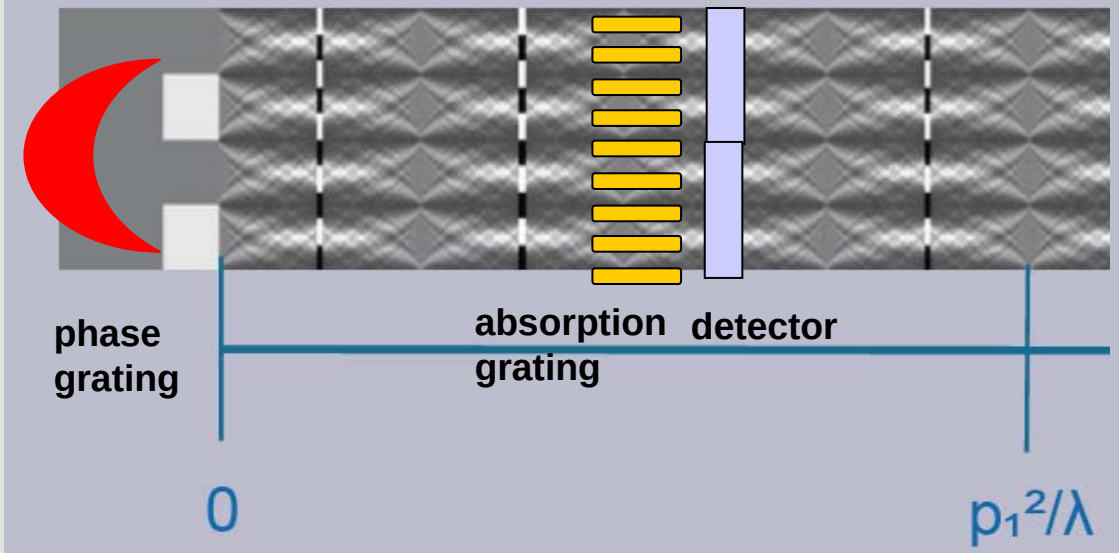
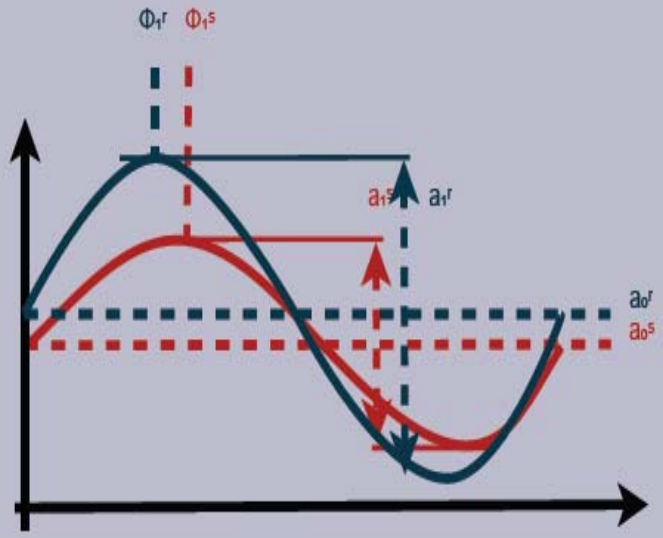
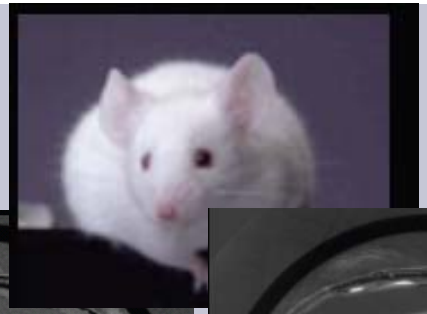




Phase Contrast Imaging – Mouse Body



absorption image

phase contrast image

tumor

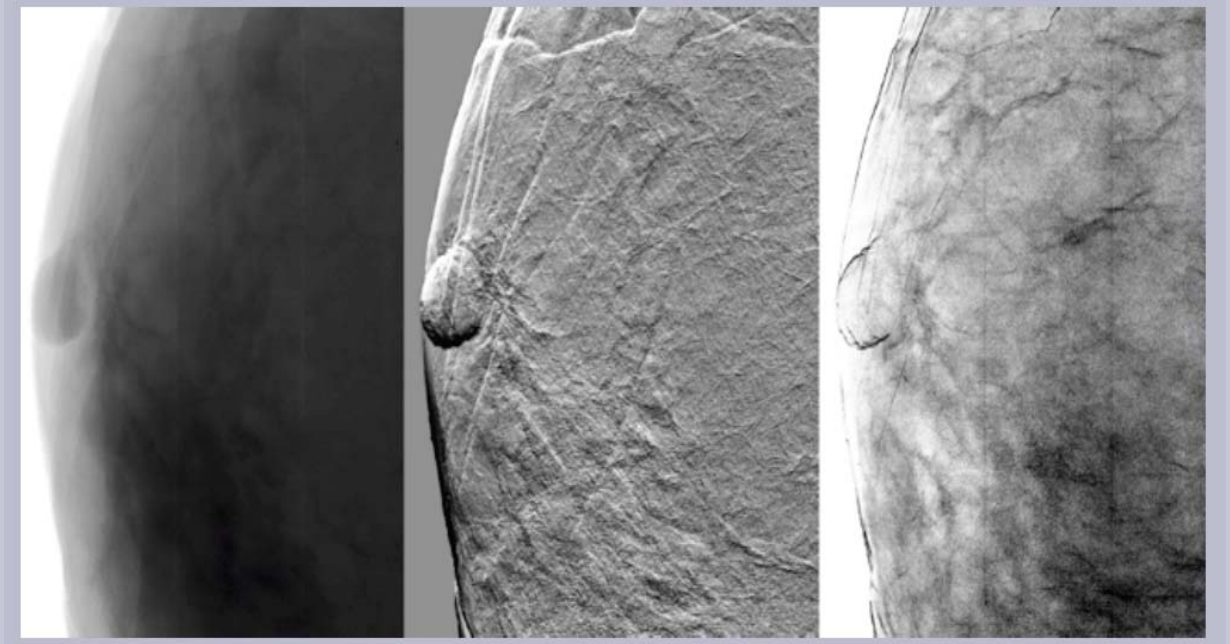
ID19, ESRF, 35 keV, A. Tapfer, M. Bech, I. Zanette, T. Weitkamp, & F. Pfeiffer

The Future Vision

currently: **pre-clinical small-animal phase-contrast CT system**

vision: **use in full body CT, mammography, radiography, etc. for human use**

first preliminary images from a woman breast



The Future Vision

currently: **pre-clinical small-animal phase-contrast CT system**

vision: **use in full body CT, mammography, radiography, etc. for human use**

……. but with a bright future

which needs strong collaboration between

- **phycists**
- **engineers**
- **physicians**

to tackle the challenges towards the future

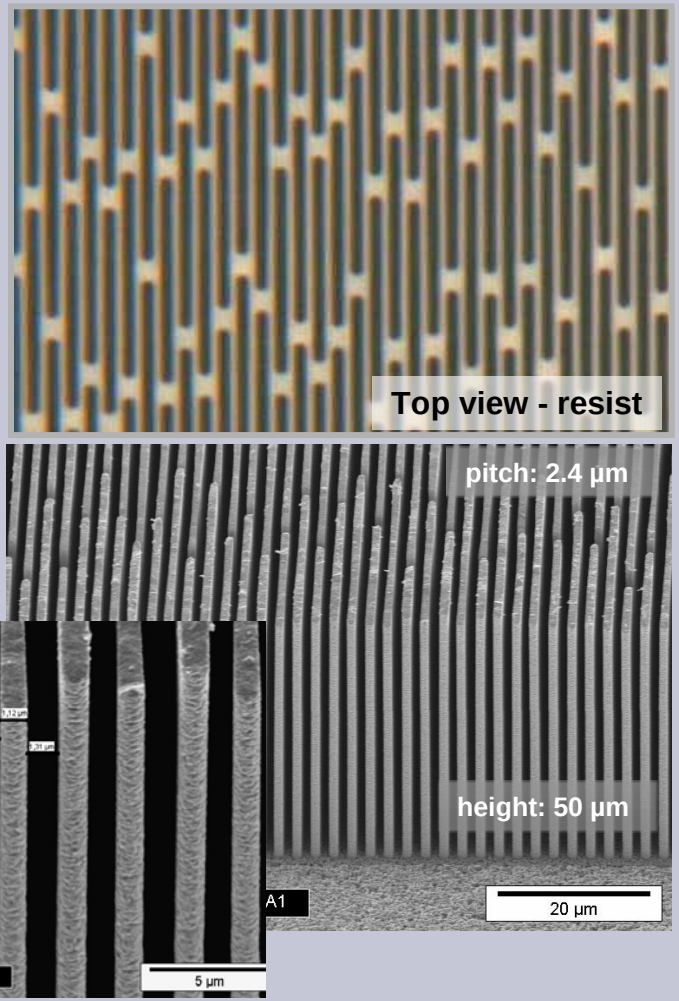
it is a long way to go ……..

The Future Challenge: Medical Use and Acceptance

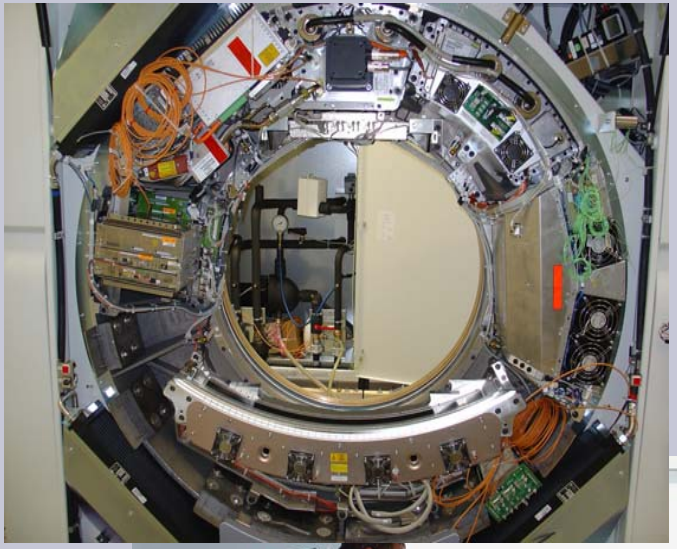
- **transfer knowledge and method from small animal diagnosis (this project) to the problem for human diagnosis (future projects)**
- **set-up a reliable system and an evaluation algorithm with a remarkable dose reduction in comparison to absorption contrast**
- **get the new method accepted by the physicians**
  - **medically relevant materials data are not yet existing**
  - **lack in experience by the physicians**
  - **correlation between phase image and tissue condition does not yet exist**

The Future Challenge: Mechanical Set-Up - An Engineering Task

absorption grating in gold to be fabricated with aspect ratio > 100 for structural width of 1 µm to 2 µm using lithography methods



very stable mechanical set-up of the CT system: relative movements of components < 1 nm under several g acceleration



Benefit of the New Method

- **X-ray images with substantial higher contrast for low absorbing materials (tissue) → the invisible gets visible in X-ray diagnostics**

- **dose reduction in CT, mammography, radiography, etc. → reduction of cancer affection by X-ray diagnostic methods (today in the US > 10.000 persons/year get cancer due to CT analysis)**

- **method will have also high potential in materials analysis**

Project Collaborators and Users