37th ICFA Advanced Beam Dynamics Workshop on Future Light Sources

X-ray Pulse Length Characterization Using the Surface Magneto Optic Kerr Effect

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Introduction

- In a SASE radiation source the duration of the x-ray pulse can be much shorter and have a very different temporal profile compared to the electron bunch in the undulator
- We were able to profile the electron bunch length with an ultrafast pump-probe laser using the electro optic effect
- Challenge is to find an interaction between x-rays and matter that can be probed by an ultrafast laser

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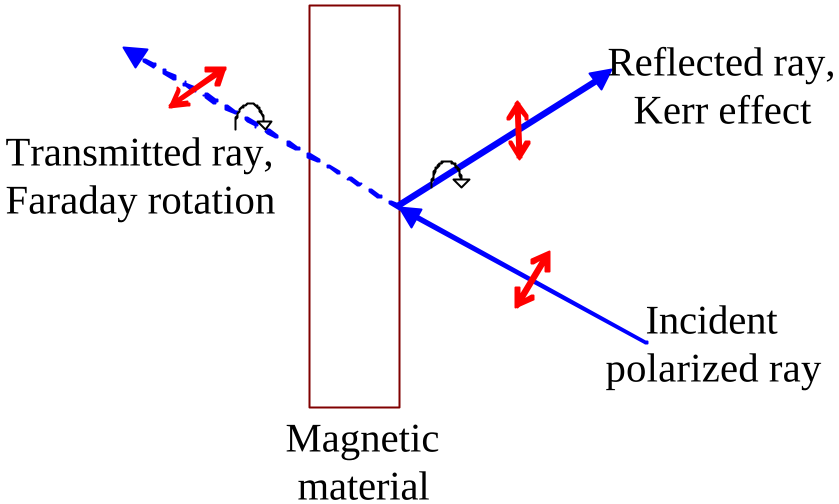
Measuring x-rays with SMOKE and mirrors!

- the Magneto Optic Kerr Effect (MOKE) describes the polarization of a light ray which is rotated according to the magnetization state of a surface from which the ray is reflected.



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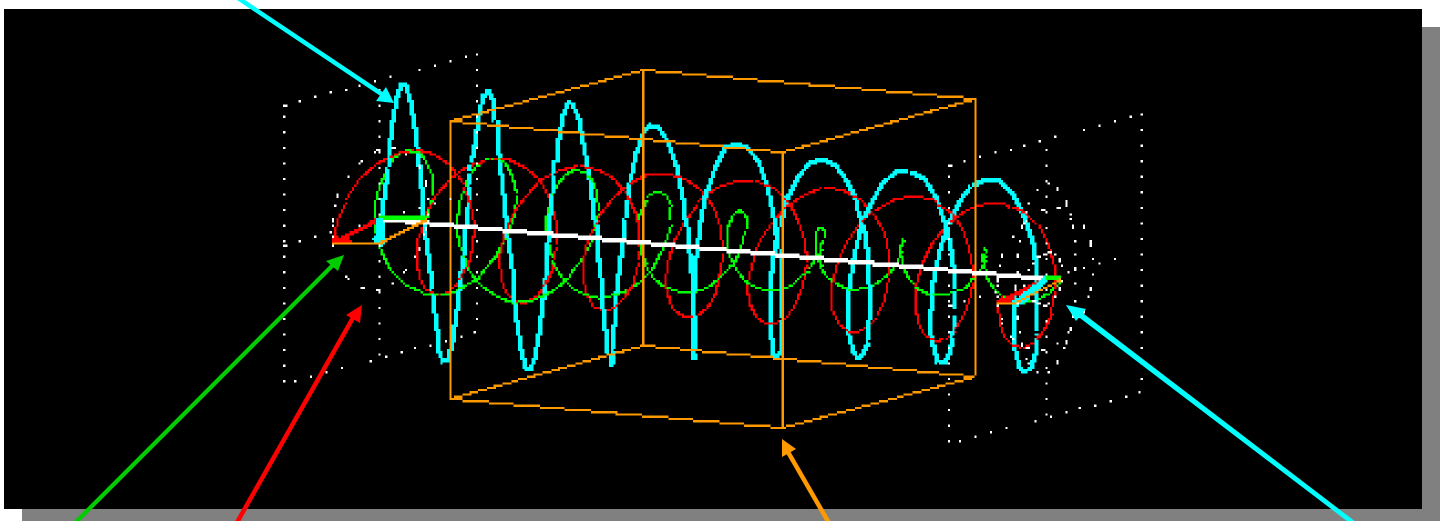
Magnetic Circular Dichroism

Plane polarized light is a superposition of two circularly polarized waves



Left circularly polarized

Right circularly polarized

A dichroic sample preferentially absorbs left or right circular polarization

Plane polarized light is converted into elliptically polarized

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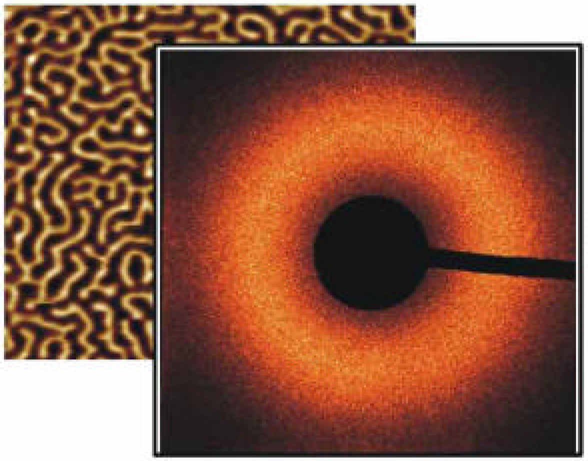
X-ray magnetic dichroism shows every atom has its moments! (Gerrit van der Laan)

- Circularly polarized light will be absorbed preferentially if aligned with the spin moment of the electron
- Magnetic dichroism is of inherent interest to the study of fast magnetic switching in thin films
- e.g. resonant scattering from the Cobalt L-Edge in a sample.



- ***FAST!*** 2p to 3d transition

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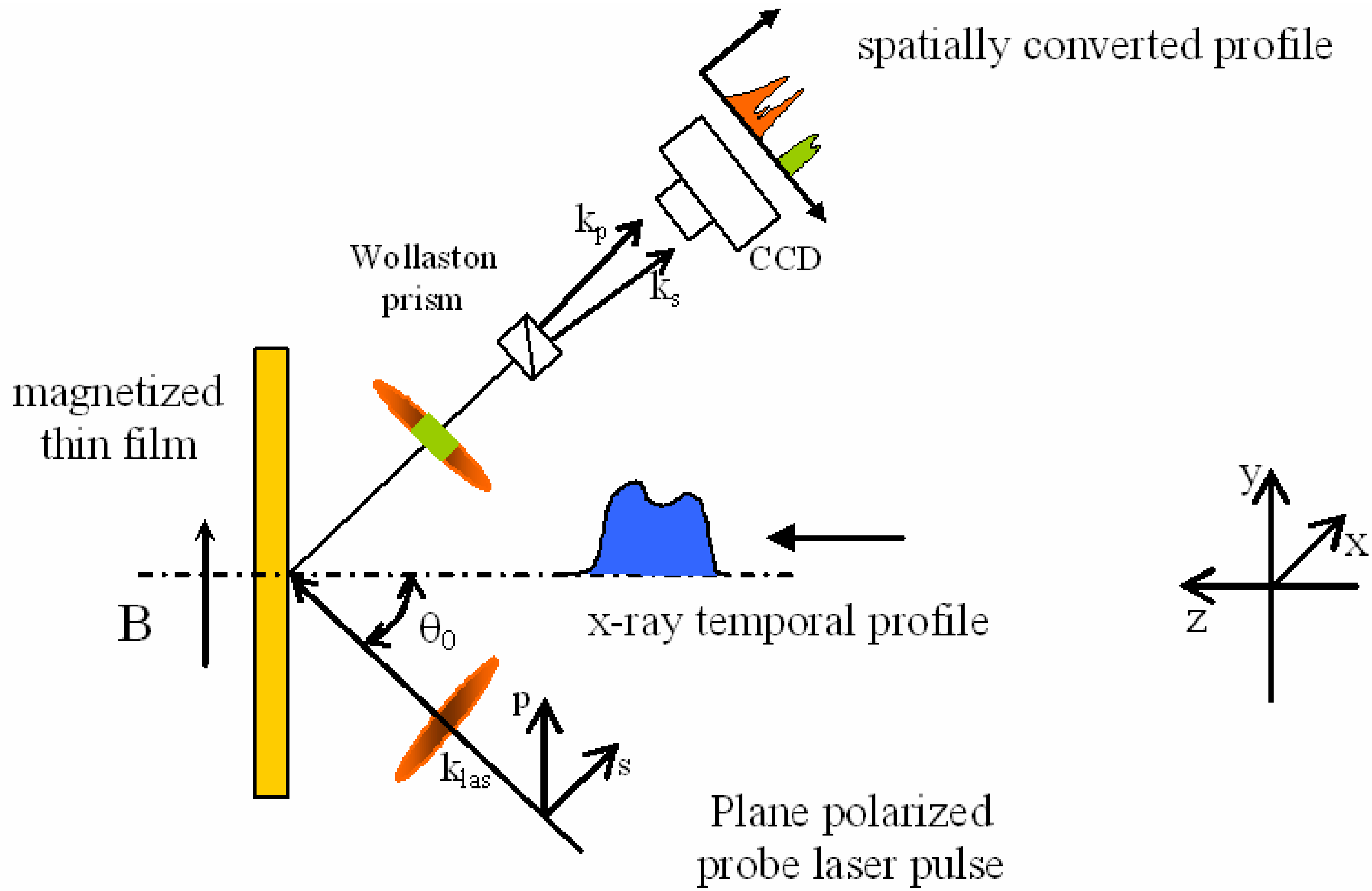
SMOKE Pump Probe Geometry



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Magnitude of the Kerr Rotation

- Magnetization, *m*, in the material causes a change in the dielectric, which when written as a tensor produces off-diagonal elements,

$$\mathbf{D} = e_0 e_x \begin{bmatrix} 1 & iQm_z & -iQm_y \\ -iQm_z & 1 & iQm_x \\ iQm_y & -iQm_x & 1 \end{bmatrix} \mathbf{E}$$

- D is the electric displacement, E the electric field and *e* the dielectric tensor. The magneto optical constant is given by the Voigt parameter ,

$$Q = i\frac{e_{xy}}{e_{xx}}$$

- The Fresnel equations for the reflection coefficients, *r*, lead to an expression for the Kerr rotations of the *s* and *p* polarizations ,

$$q_K^p = \frac{r_{sp}}{r_{pp}} = \frac{\cos q_0 \left(m_z + m_y \tan q_1\right)}{\cos\left(q_0 + q_1\right)} \cdot \frac{i n_0 n_1 Q}{\left(n_1^2 - n_0^2\right)}$$

$$q_K^s = \frac{r_{ps}}{r_{ss}} = \frac{\cos q_0 \left(m_z - m_y \tan q_1\right)}{\cos\left(q_0 - q_1\right)} \cdot \frac{i n_0 n_1 Q}{\left(n_1^2 - n_0^2\right)}$$

- where n_0 and n_1 are the refractive indices for vacuum and of the magnetic material, and q_0 and q_1 are the angles of the incident and transmitted ray in the magnetic medium

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Thin Films

- Surface effects are not limited by transit times through thick samples, or hindered by mismatches in index of refraction (which limits EO)
- Use holmium with its L-shell at 9.394 keV.
  - It has the highest magnetic moment of 10.6µB of any naturally occurring element.
  - Because of this it has been used to create the highest known magnetic fields by placing it within high strength magnets as a pole piece or magnetic flux concentrator.
  - The Kerr rotation of thin films of Fe-Ho mas been measured to be 0.43 deg at 800 nm.

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Temporal Resolution

- Reflected laser light penetrates surface to a depth of ~20 nm
- Spin-orbit coupling transitions are sub-femtosecond
- We are limited only by the bandwidth limited compressed laser pulse resolution of ~5 fs

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Dick Tracy said it all in 1935:

"the nation that controls magnetism will control the universe",

Chester Gould, Tribune Media Services, 1935.

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