Mini PSI summer course August 19 -21:

X-Ray Interactions with Matter - From Basics to Non-Linear Effects

Joachim Stöhr, Stanford University, Guest professor ETH Zurich

Time: from 14:00 – 17:00, Tue 19.8./Wed 20.8./Thu 20.8.
Place: PSI west side, seminar room WBGB/019 (building of the time out, in front of the SLS)
http://www.psi.ch/how-to-find-us

Format: Two lectures per day with coffee break, extensive discussions
Audience: PhD students, postdocs and staff scientist (limited to30 people)
Because of the evolutionary nature of the lectures, participants should plan on attending all lectures.
Advanced registration is required.
Registration: via email to frithjof.nolting@psi.ch (There is no fee for this tutorial)

Lecture 1:

- *The Description of X-Rays*
  Coulomb fields, virtual fields and electromagnetic radiation
  From classical to quantized fields – birth of the photon
  Waves, fields, polarization states, coherence, photon modes, zero-point field
  Evolution of x-ray sources - toward the diffraction and transform limit

- *Classical Theory of X-Ray Interactions with Matter*
  From Thomson to resonant scattering
  Link of resonant scattering and x-ray absorption: field and photon pictures
  The Born approximation and scattering factors
  From atoms to solids: the frequency dependent refractive index
  Link of the refractive index and atomic scattering factors
  Polarization dependent effects

Lecture 2:

- *Quantum Theory of X-Ray Interactions*
  Kramers-Heisenberg perturbation theory
  1st order processes: Thomson scattering, x-ray absorption, spont. & stimul. emission
  2nd order processes: Spont. & stimul. resonant x-ray scattering
  X-ray source requirements for the observation of stimulated processes

- *Beyond Bragg Diffraction – Coherent Imaging*
  From Huygens' principle to Rayleigh-Sommerfeld diffraction theory
  The meaning of forward scattering: from small angle scattering to speckle
  Real space microscopy versus diffractive imaging – pros and cons
  From reciprocal to real space – solution of the phase problem

Lecture 3:

- *Non-Linear X-Ray Interactions: Atomic Response*
  Historical development: From NMR to lasers to x-ray lasers
  Bloch-Rabi theory of strong field interactions
  When does the Kramers-Heisenberg treatment break down?

- *Non-Linear X-Ray Interactions: Solids*
  Stimulated forward scattering by a thin film
  Modification of the optical constants
  Effect on the coherent diffraction pattern
  Link to the susceptibility formulation in non-linear optics

Food for thought…

The lectures will address some vexing questions you, like me, may have always wondered about……
If you can answer the following questions, the course is too simple for you!

X-rays
- Does an x-ray photon have a size?
- Why is the mysterious zero-point or vacuum field important in x-ray science?
- How can we picture a classical electromagnetic wave in terms of photons?

X-ray interactions
- Is there a simple picture to visualize the size of the x-ray absorption cross section?
- Is the transmitted intensity through a sample ever significantly affected by scattering?
- Why can we neglect the direct interaction of the x-ray magnetic field with spins and magnetic moments?

Quantum interactions
- Does spontaneous x-ray emission occur by chance or is there a driving force?
- Is the size of the zero-point field the same as the size of the field of a single photon?
- Why do all storage ring source experiments occur one-photon-at-a-time?

Diffractive imaging
- Can the famous and mysterious Huygens principle be derived from the Born approximation?
- Is the small angle speckle pattern due to scattering or absorption?

Non-linear interactions
- If there are two photons in the x-ray coherence volume, does stimulated scattering always occur?
- Does stimulated scattering scale with the number of atoms or the number of atoms squared in the beam?