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Refraction and absorption of x rays by laser-dressed atoms

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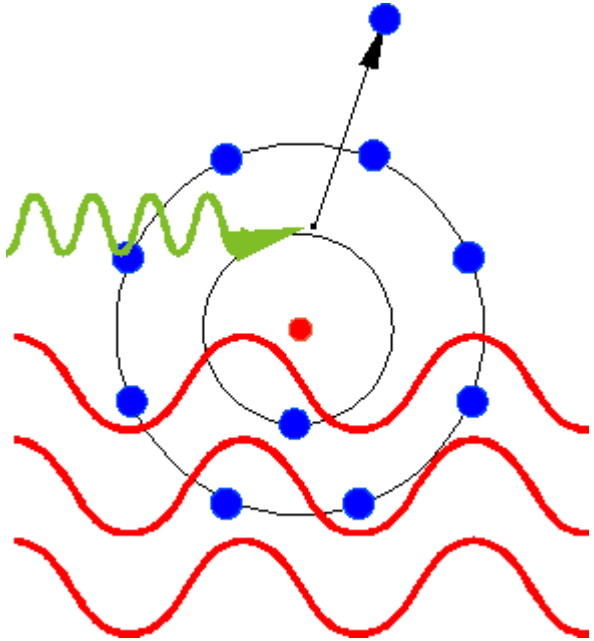
Contents

X-ray probe of laser-dressed atoms

- Atoms in a **laser**
- Probed by **x rays**
- Atomic ground state electrons are neither excited nor ionized
- Rydberg final states are dressed



[Buth, Santra, Phys. Rev. A 75, 033412 (2007)]

Laser characteristics

- Ti:sapphire system $800\ \mathrm{nm},\ I = 10^{13}\ \mathrm{W\,cm^{-2}}$
- **Keldysh parameter** for Ne $3p$ Rydberg orbitals

$$\gamma = \sqrt{\frac{I_{3p}}{2\,U_p}} = 1.5 \approx 1$$

- **Strong field regime**
- Multiphoton physics
- Need sophisticated theoretical treatment!

[Buth, Santra, Young, Phys. Rev. Lett. 98, 253001 (2007)]

Quantum electrodynamic description of atoms

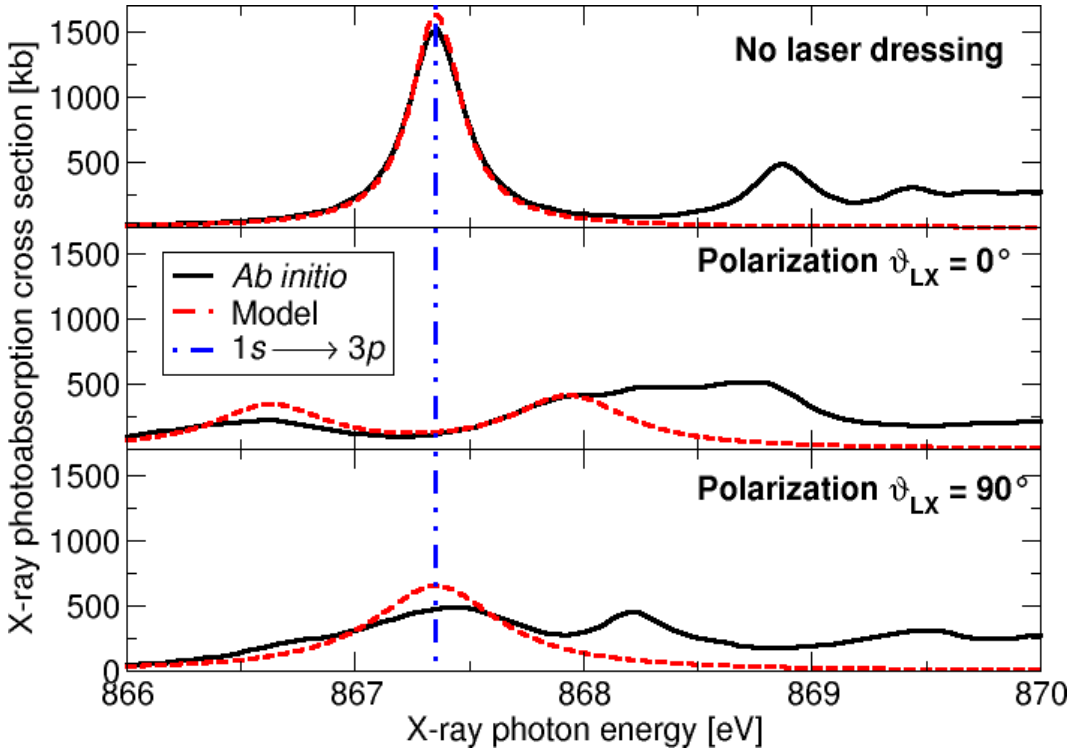
- **Hartree-Fock-Slater** one-electron model
- **Complex absorbing potential** (CAP) to treat continuum electron
- Core hole decays => extra line width
- Laser is described by a **Floquet-type** matrix
- X-ray probe in one-photon perturbation theory

$$\sigma_{1s}(\omega_X, \vartheta_{LX}) = \sigma_{1s}^{\parallel}(\omega_X)\cos^2(\vartheta_{LX}) + \sigma_{1s}^{\perp}(\omega_X)\sin^2(\vartheta_{LX})$$

[Buth, Santra, Phys. Rev. A 75, 033412 (2007)]

Neon K edge

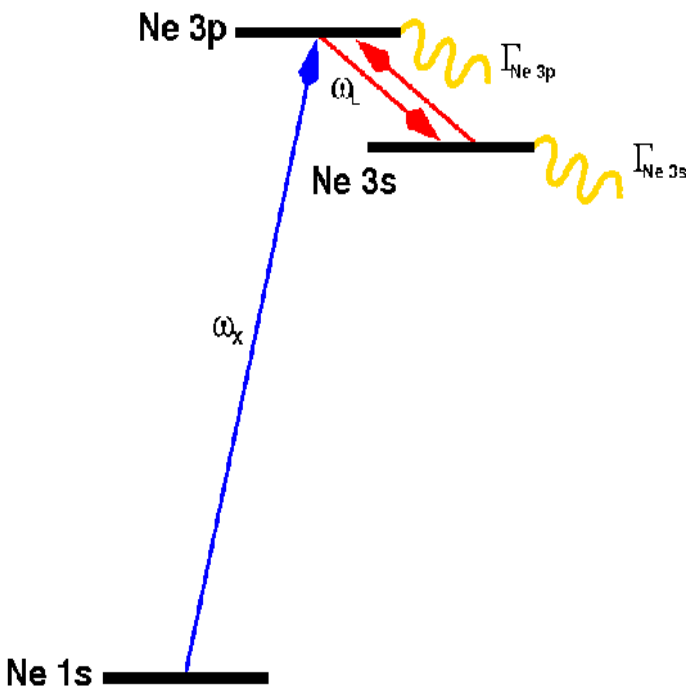
- For $\theta_{LX} = 0°$ **transparency** at $1s \rightarrow 3p$ transition
- Suppression for $\theta_{LX} = 90°$
- Λ -type **three-level model**



[Buth, Santra, Young, Phys. Rev. Lett. 98, 253001 (2007)]

Electromagnetically induced transparency (EIT)

- Gas is **opaque** for $\mathrm{Ne\,1s} \rightarrow \mathrm{Ne\,3p}$ transition
- Gas becomes **transparent** by laser on $\mathrm{Ne\,3p} \rightarrow \mathrm{Ne\,3s}$ transition
- **Electromagnetically induced transparency** (EIT)
- Only EIT for **optical** wavelengths has been studied

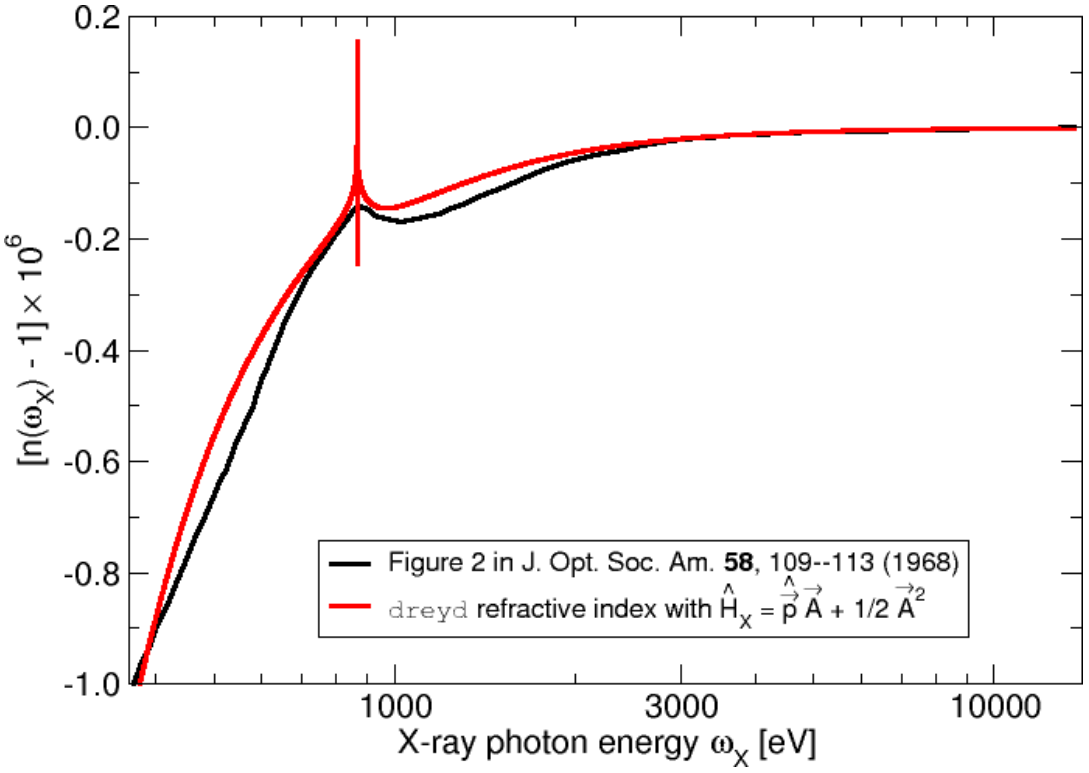


[Buth, Santra, Young, Phys. Rev. Lett. 98, 253001 (2007)]

Index of refraction

- Refractive index from Maxwell equations
- No laser
- Comparison with experiment
- Interaction with x rays

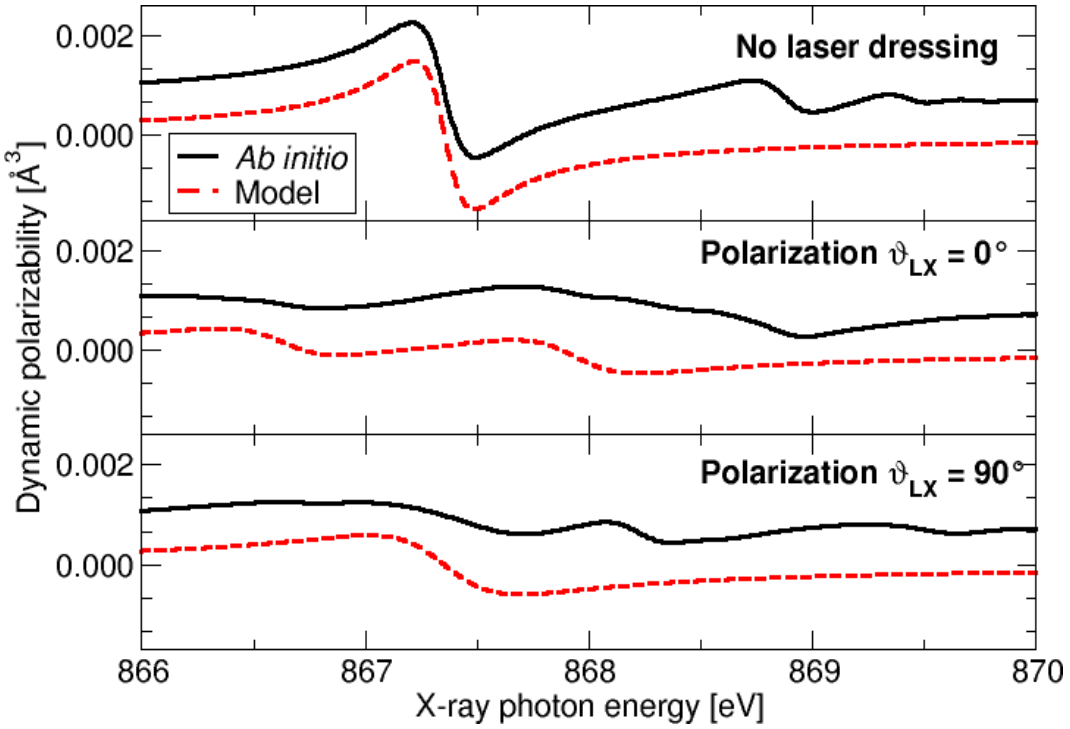
$$\hat{H}_X = \hat{\vec{p}} \cdot \vec{A}_X + \frac{1}{2} \vec{A}_X^2$$



Polarizability of laser-dressed neon atoms

- EIT at **optical** frequencies changes refraction and dispersion dramatically
- Instead for **x rays** small effect
- Interaction with x rays

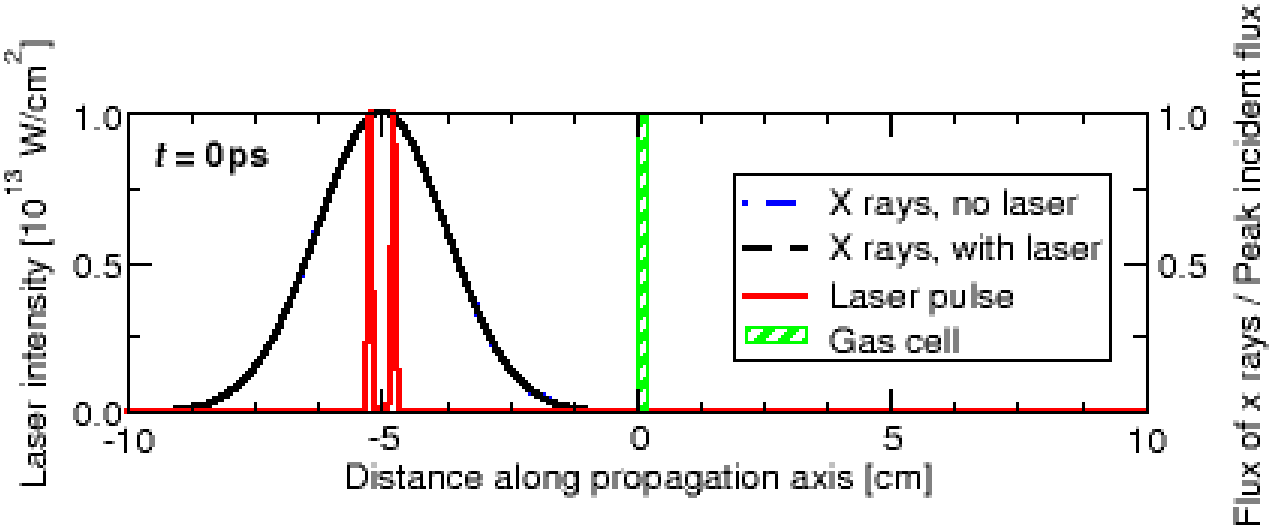
$$\hat{H}_X = -\vec{r}\cdot\vec{E}_X$$



[Buth, Santra, Young, Phys. Rev. Lett. 98, 253001 (2007)]

Ultrashort pulse shaping of x rays

- Neon gas cell
- Laser pulse shape is **imprinted** on x rays
- **Femtosecond** x-ray pulses
- All x-ray pump-probe experiments
- Amplitude modulation only



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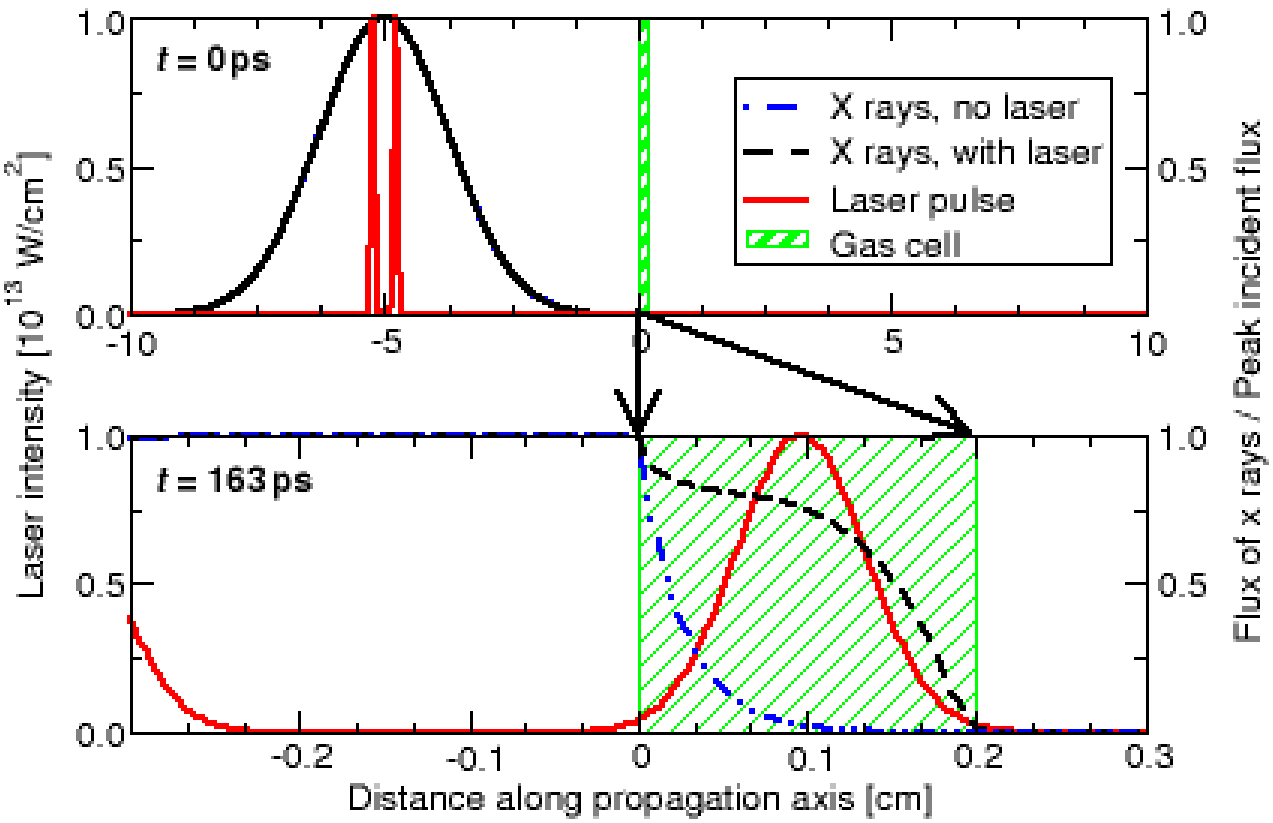

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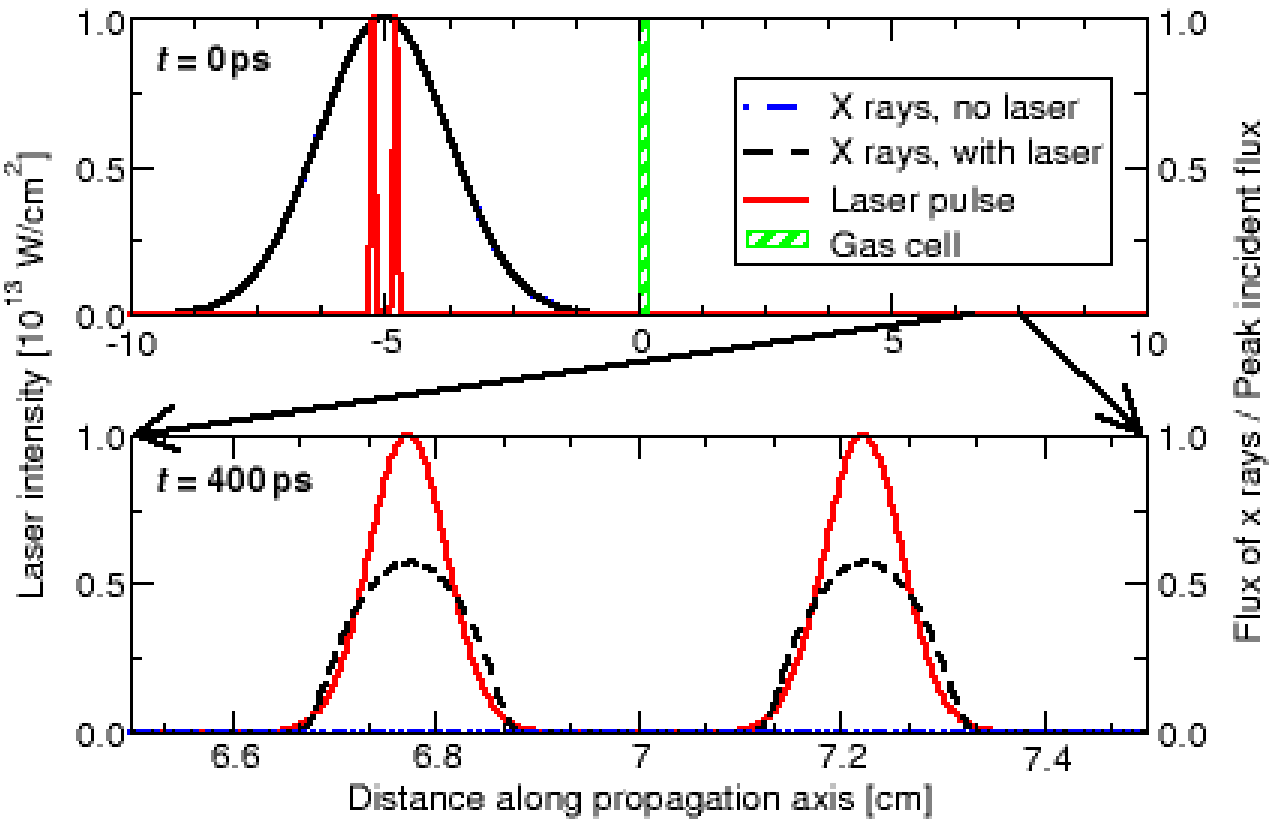

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Conclusion

- Theory of laser-dressed atoms probed by x rays
- Laser dressing is **multiphoton physics**
- X-ray probe is a **one-photon** process
- **Electromagnetically induced transparency** (EIT) for x rays
- **Femtosecond** pulse shaping of x rays

Acknowledgment

Linda Young

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