Attosecond Pulses Generation at High Repetition Rate

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Problem

Attosecond pulses sources are all based on high harmonics generation (**HHG**) from gases.

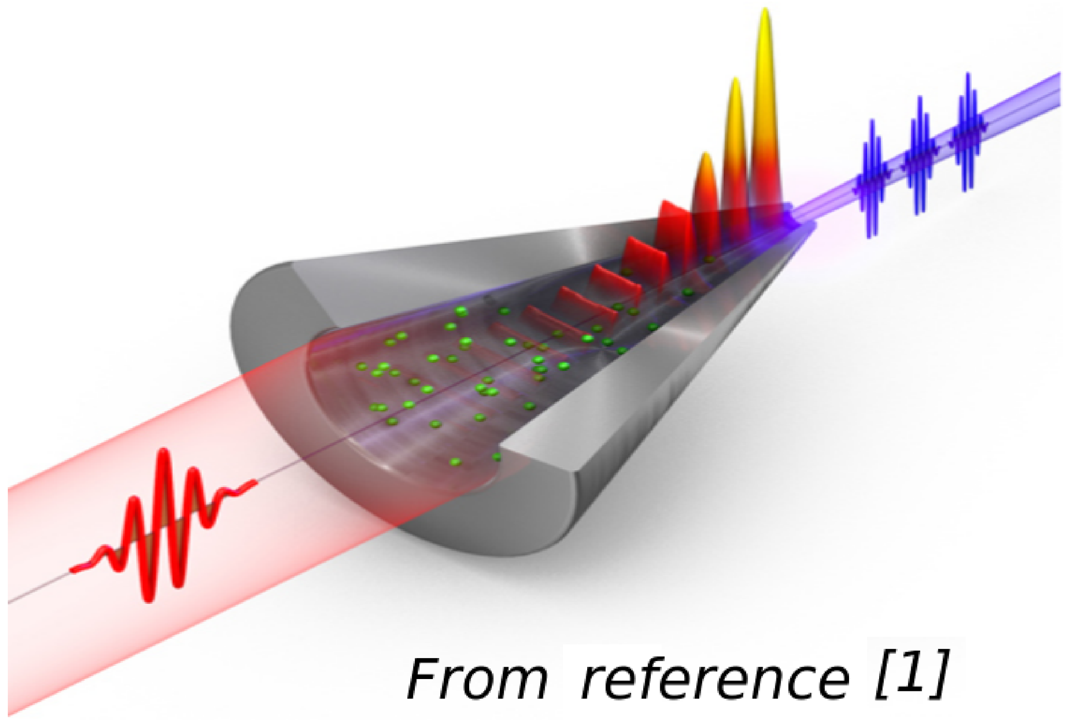
Problems:

- 40 eV photon energies requires $I_L > 10^{14} W/cm^2$
- **Repetition rate limited to 1 kHz** by amplification process
- **Very complex beam line**

We *get rid of the two problems* with our proposal

Contributions

Experimental setup



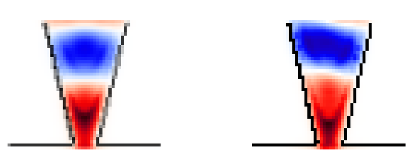
We base our proposal on a recent observation [1] of driver *field enhancement* based on **plasmonic effects**:

- Tapered nano-plasmonic waveguide
- Driving pulse ($\lambda = 800nm$) excites surface plasmon polariton (SPP)
- **Adiabatic nano-focusing** of SPP to localized plasmon (at tip)
- Intensity enhancement $\sim 10^3$
- HHG at repetition rate of 80 MHz !!

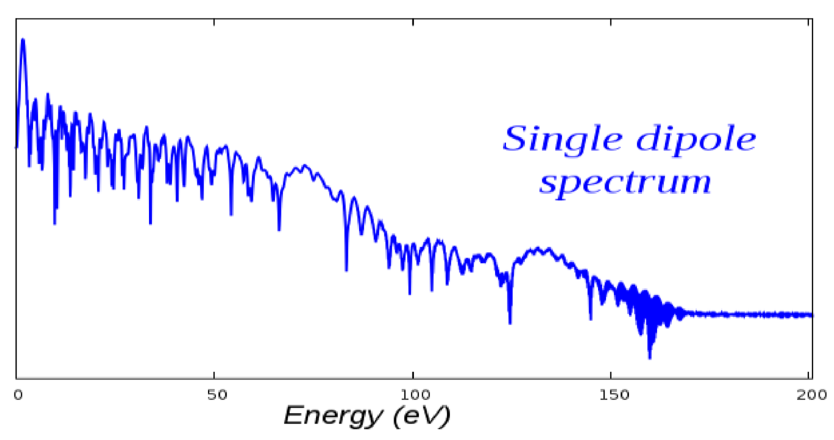
Method

"Sandwitch" procedure:

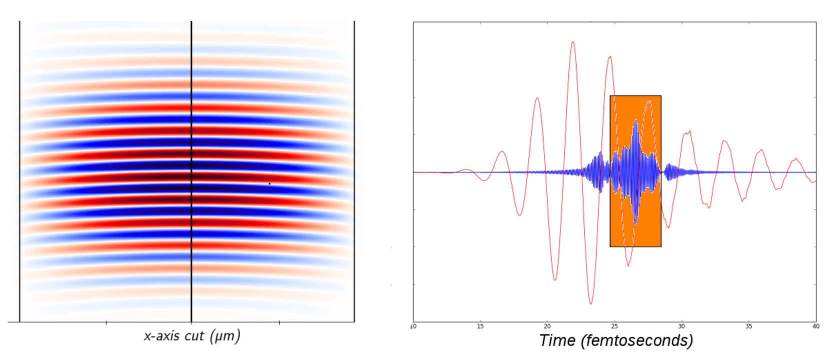
1. **Plasmonic field**
   FDTD simulation of Plasmonic field enhancement
   (normal & oblique incidence)



2. **Atomic response**
   Numeric solution of TDSE
   (Time Dependent Schrödinger Equation) for
   H atoms in the enhanced field



3. **Attosecond pulse**
   FDTD simulation of harmonic radiation from atomic responses:
   time structure and *coherence*



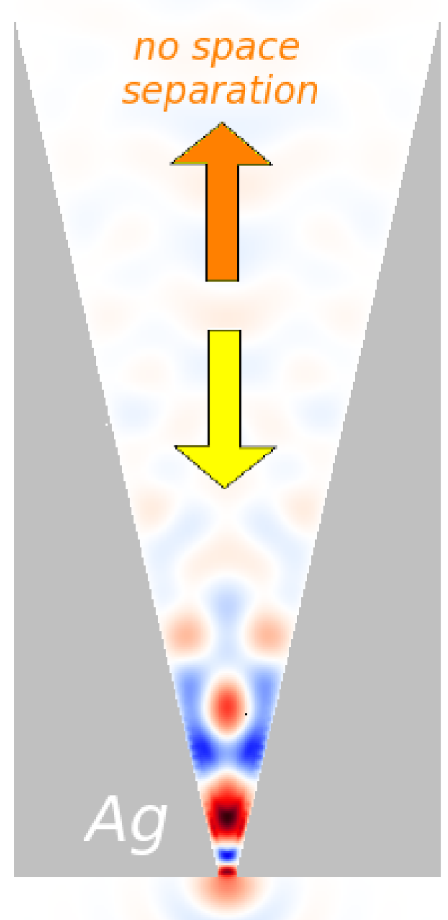
Conclusions

The proposed device can deliver isolated attosecond pulses at photon energies of $\sim 30-40\,eV$ at 100 MHz repetition rate. At atmospheric pressure a single conical waveguide delivers about 10^{-6} the harmonic intensity of a gas harmonic source. Due the high repetition rate and the possibility to increase the gas pressure, the average photon flux can exceed the present sources by a factor of 10 or more.

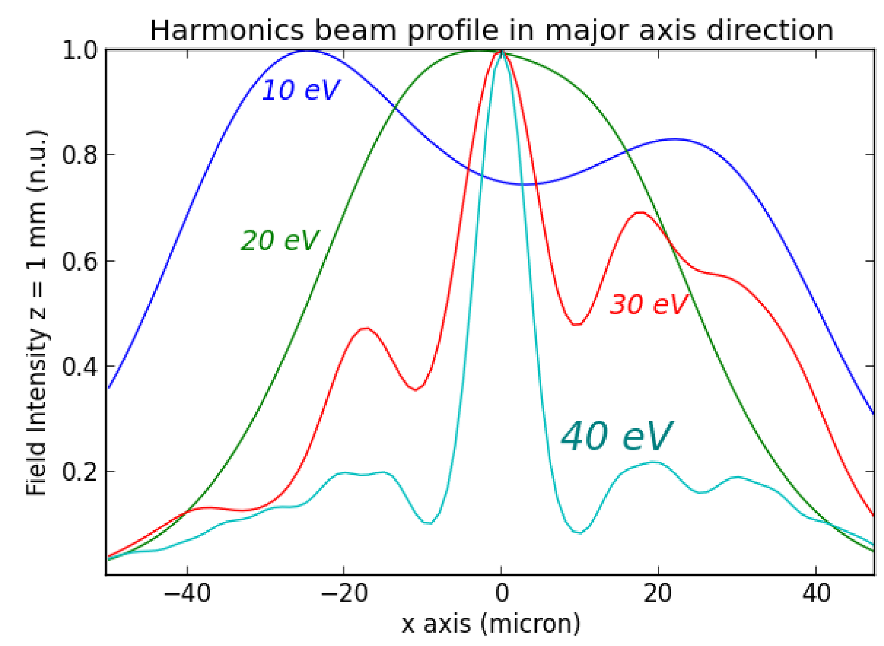
Results

Plasmonic field enhancement

Normal Incidence

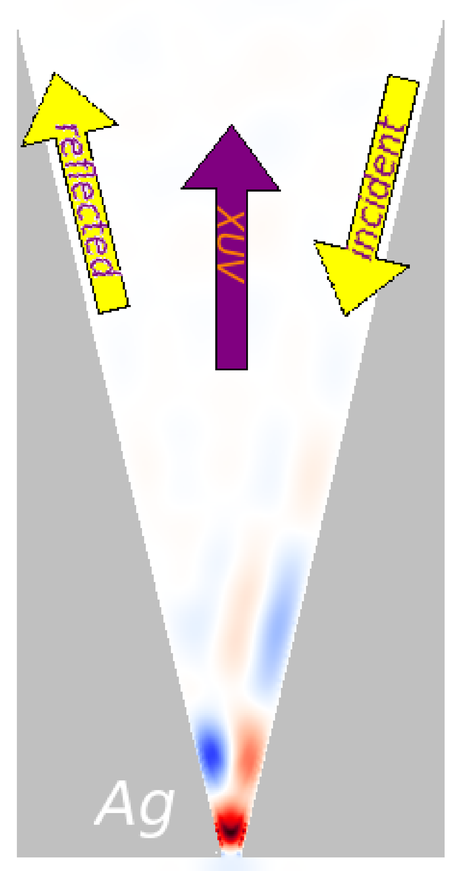


Normal incidence: **reflection** of collimated harmonics beam



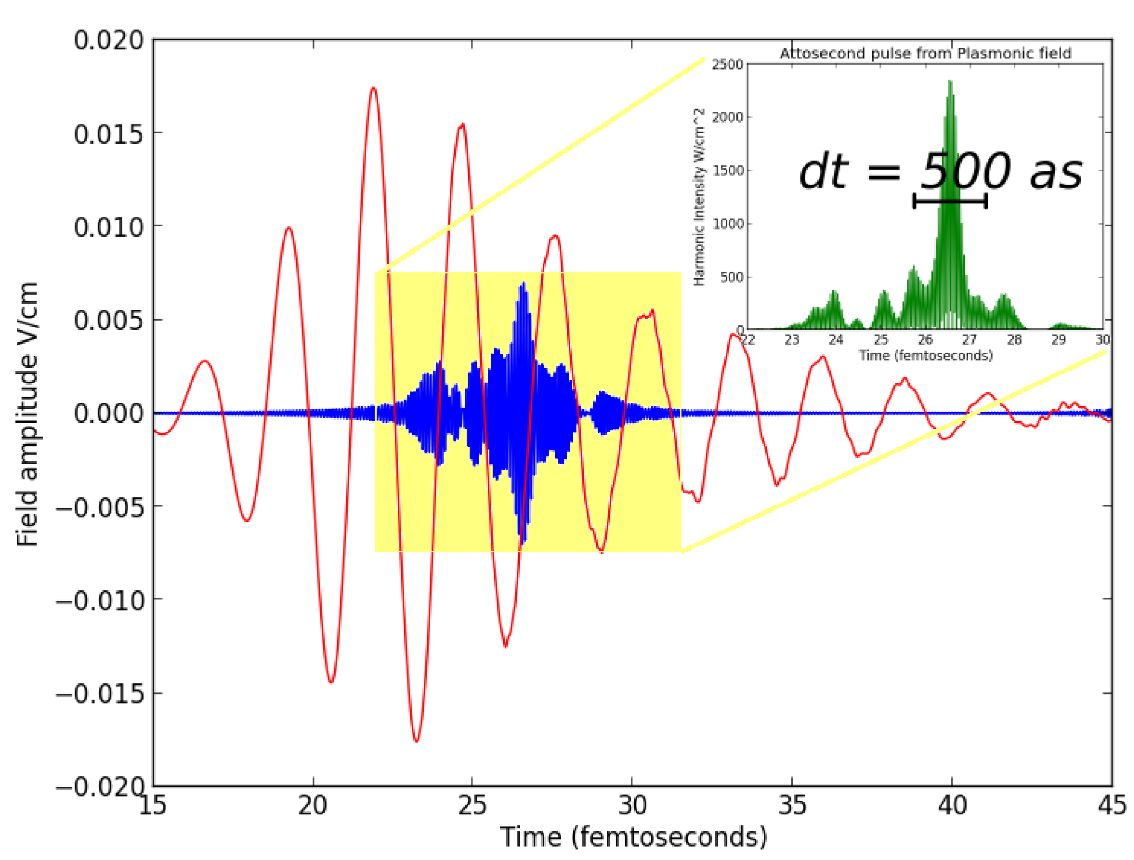
Oblique incidence: Space separation of the harmonics beams.

Oblique Incidence



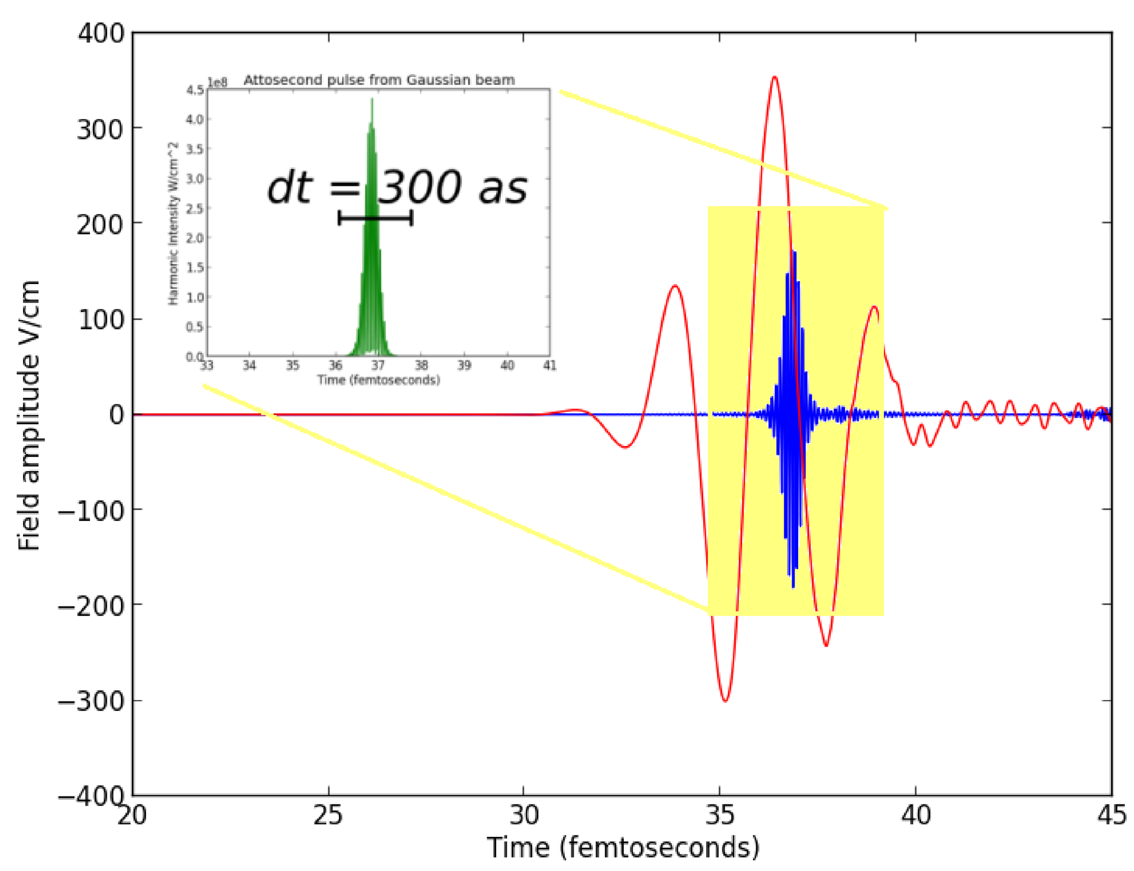
Attosecond Pulse Generation

Nanoplasmonic Waveguide



Carrier frequency	$\lambda_C = 43eV$
Peak Intensity	$I_p = 2.5 \cdot 10^3 W/cm^2$
Time duration	$\Delta t = 500as$
Yield	10^{-3} photons/pulse
Photon flux	$\Phi = 10^5 s^{-1}$
Beam divergence	$\Theta = 2°$

Reference Gaussian Pulse



Carrier frequency	$\lambda_C = 40eV$
Peak Intensity	$I_p = 4 \cdot 10^8 W/cm^2$
Time duration	$\Delta t = 300as$
Yield	10^3 photons/pulse
Photon flux	$\Phi = 10^6 s^{-1}$
Beam divergence	$\Theta \sim \pi\lambda_C/w_0$

Aknowledgements

Vienna Computational Materials Laboratory
ViCoM

References

[1] I. Park *et al.* Plasmonic generation of ultrashort extreme-ultraviolet light pulses. *Nature Photonics 2011, 5, 11, 677-681*