Demonstration of EEHG at the 14th harmonic

Dao Xiang, On behalf of the ECHO-75 team
SLAC National Accelerator Laboratory

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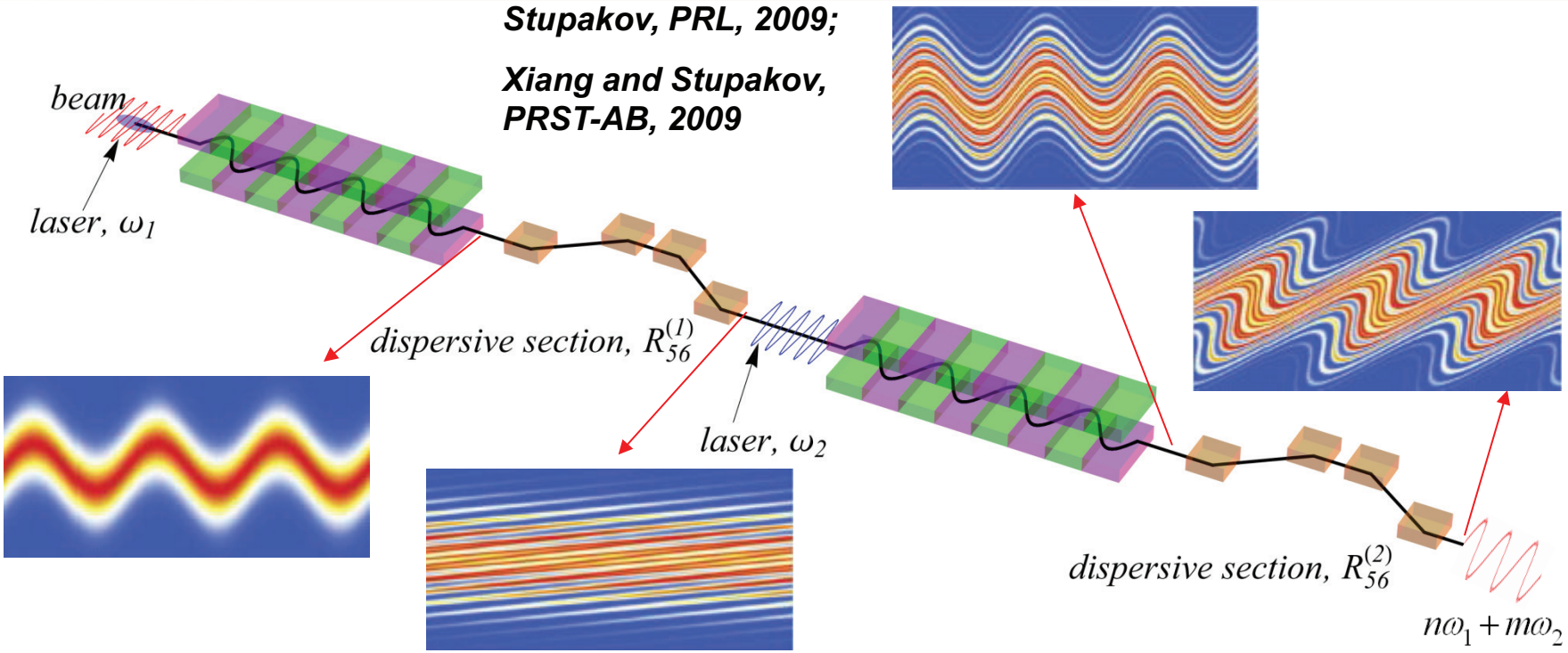
U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

EEHG (Echo-enabled harmonic generation)

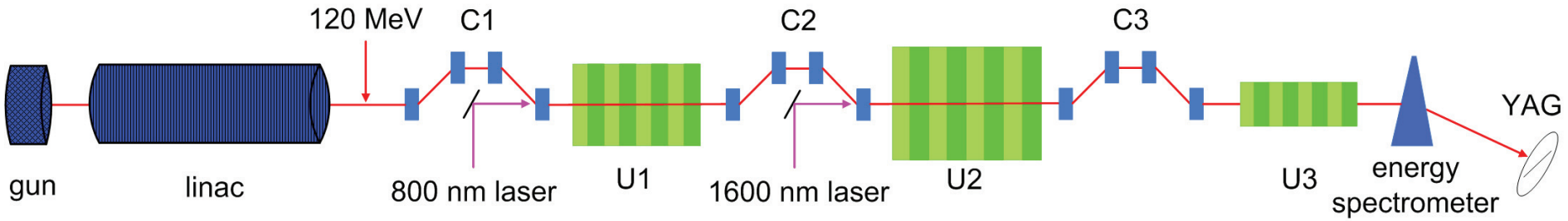


- First laser to generate energy modulation in electron beam
- First strong chicane to split the phase space
- Second laser to imprint energy modulation
- Second chicane to convert energy modulation into density modulation

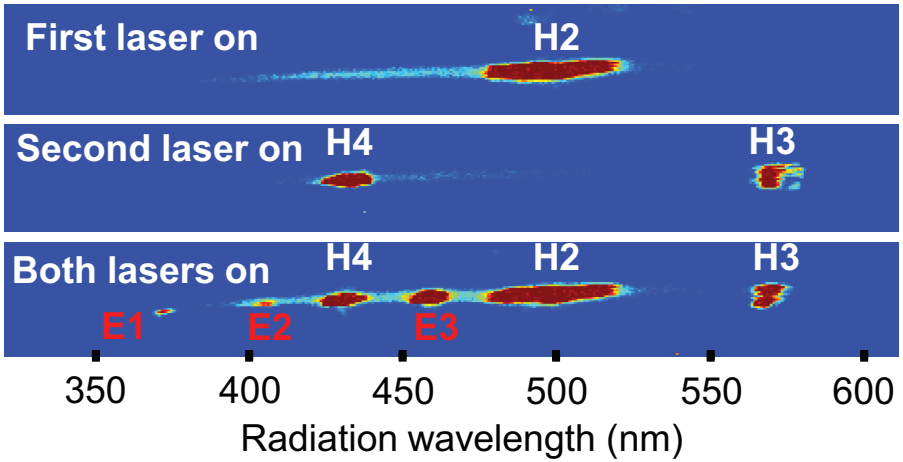
$$n >> \Delta E/\sigma_E$$

Demonstration of EEHG at the 14th harmonic

Previous EEHG results at SLAC's NLCTA (Next Linear Collider Test Accelerator)



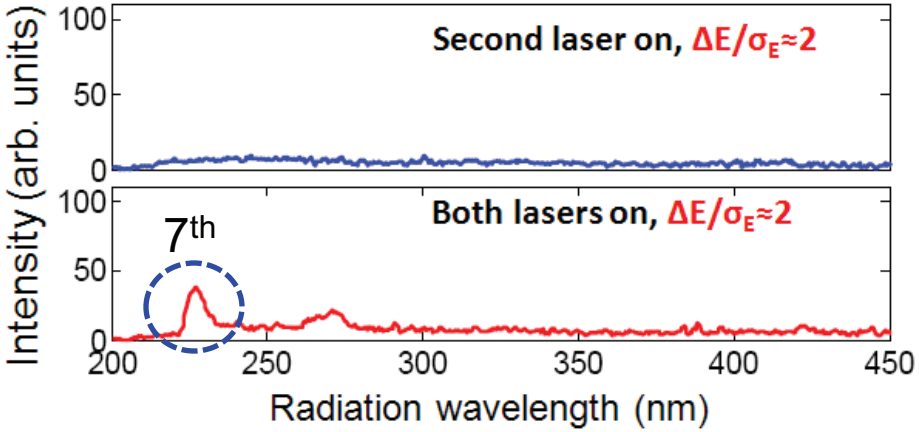
2010



- EEHG at the 4th harmonic: $\Delta E/\sigma_E \approx 80$
- Phase space correlation can be preserved

Xiang *et al., PRL 105, 114801* (2010)

2011

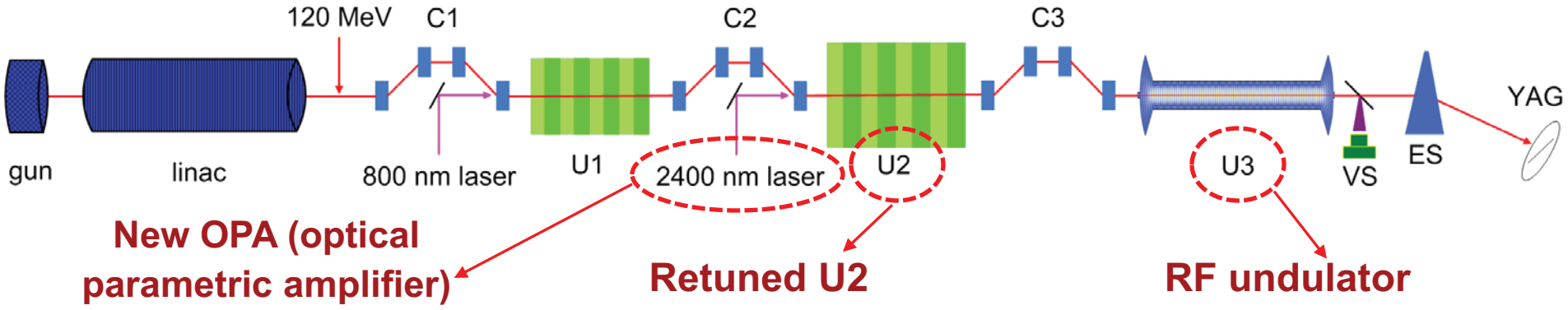


- EEHG at the 7th harmonic: $\Delta E/\sigma_E \approx 2$
- $n >> \Delta E/\sigma_E$

Xiang *et al., PRL 108, 024802* (2012)

Demonstration of EEHG at the 14th harmonic

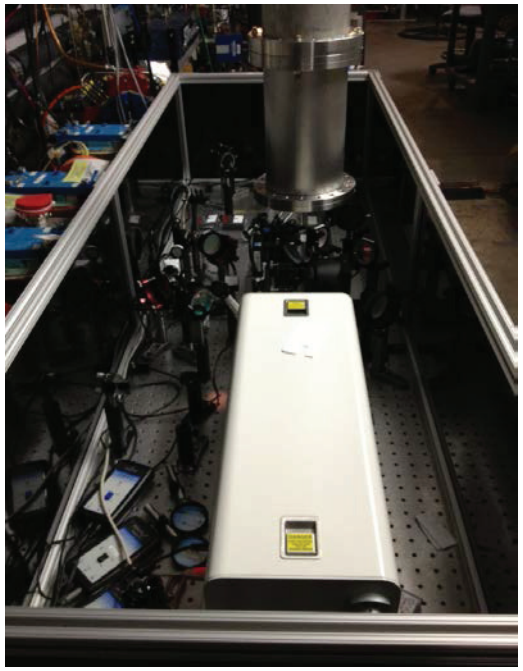
Upgraded EEHG beam line at SLAC's NLCTA



New OPA (optical parametric amplifier)

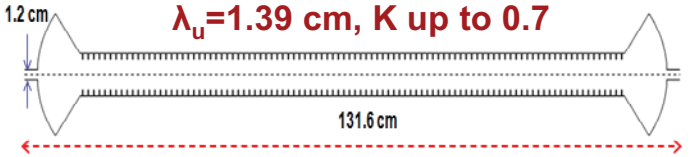
Retuned U2

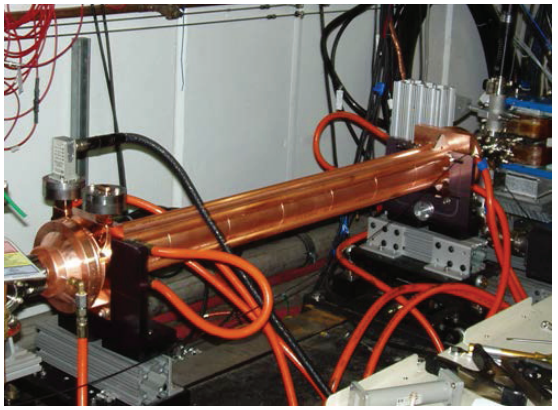
RF undulator



λ_u=5.5 cm, K=2.76

λ_u=1.39 cm, K up to 0.7





Tantawi *et al., submitted*

Demonstration of EEHG at the 14th harmonic

Upgraded EEHG beam line at SLAC's NLCTA

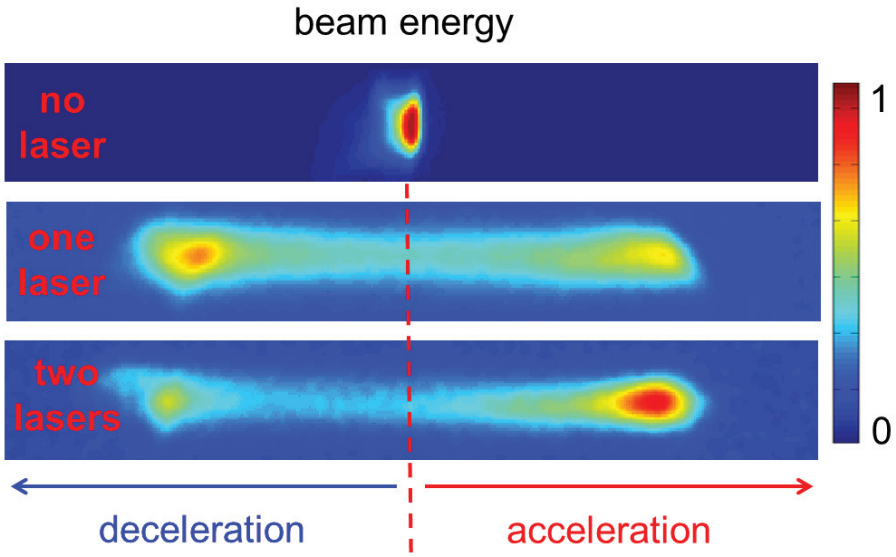
SLAC

Undulator U2 retuned to 2400 nm in 10/2012

Undulator K value is confirmed through harmonic interaction

Cascaded optical inverse FEL through 3rd harmonic interaction

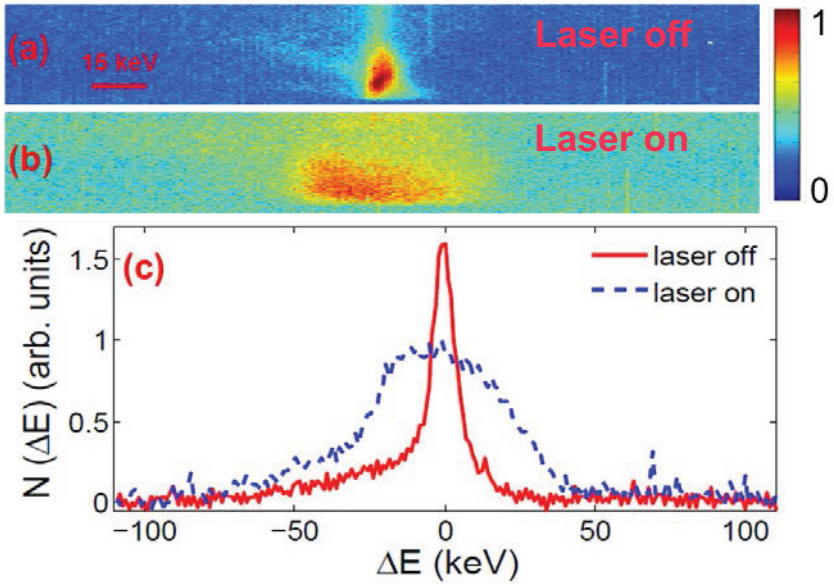
E=120 MeV, λ_r=2.4 um, laser at 800 nm



Dunning *et al., PRL 110, 244801* (2013)

Harmonic interaction up to 15th order (a new record; useful for pSASE, etc.)

E=54 MeV, λ_r=12 um, laser at 800 nm

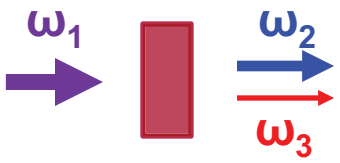


Xiang *et al., submitted*

Demonstration of EEHG at the 14th harmonic

Upgraded EEHG beam line at SLAC's NLCTA

OPA installed in 04/2013 (tunable from 1.2 um to 2.6 um)



$\omega_1 = \omega_2 + \omega_3$

In an OPA, one photon is divided into two photons, the sum energy of which is equivalent to the energy of the photon of the pump.

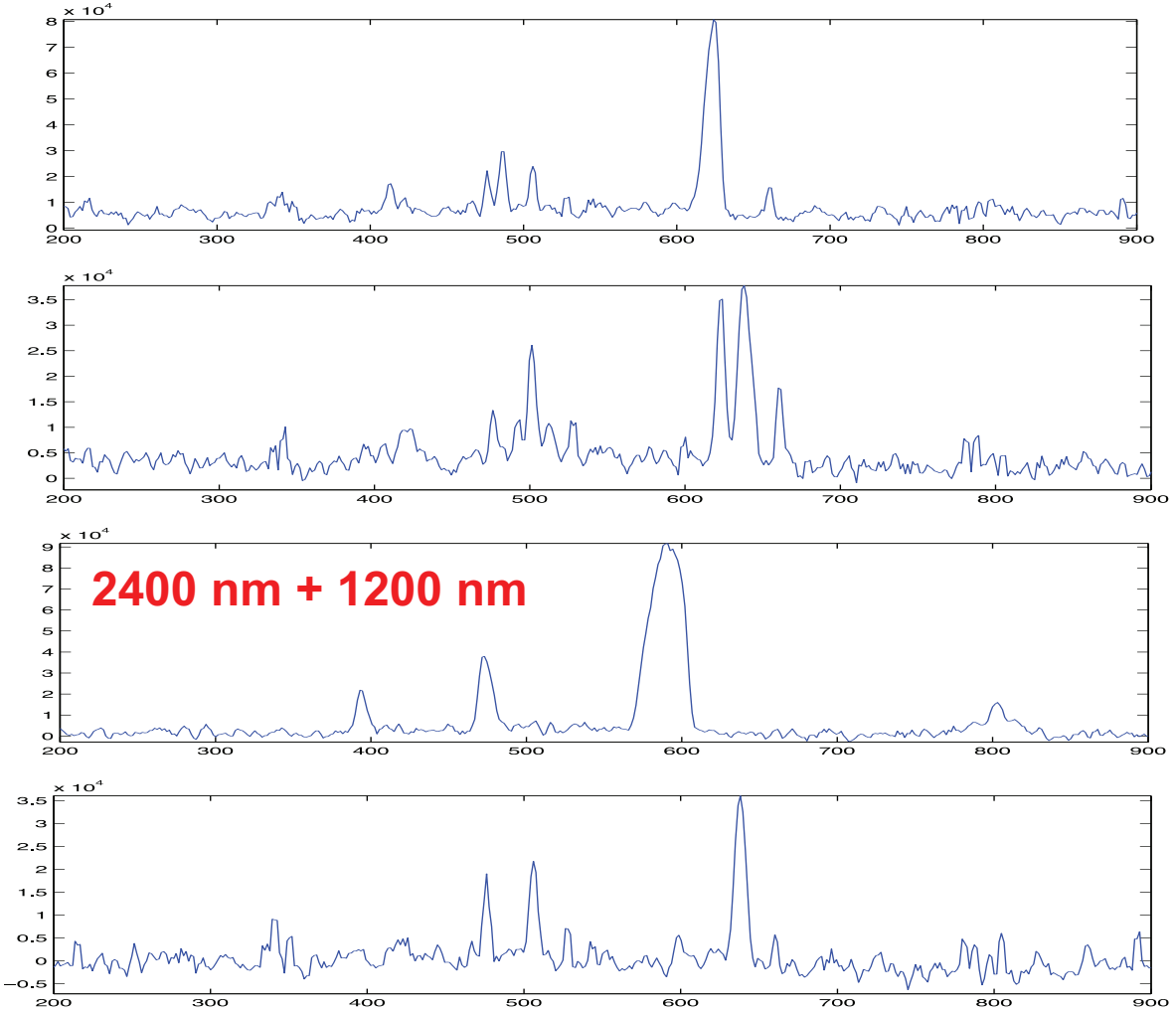
pump = signal + idler

800 nm -> 1160 nm + 2578 nm

800 nm -> 1180 nm + 2484 nm

800 nm -> 1200 nm + 2400 nm

800 nm -> 1220 nm + 2323 nm

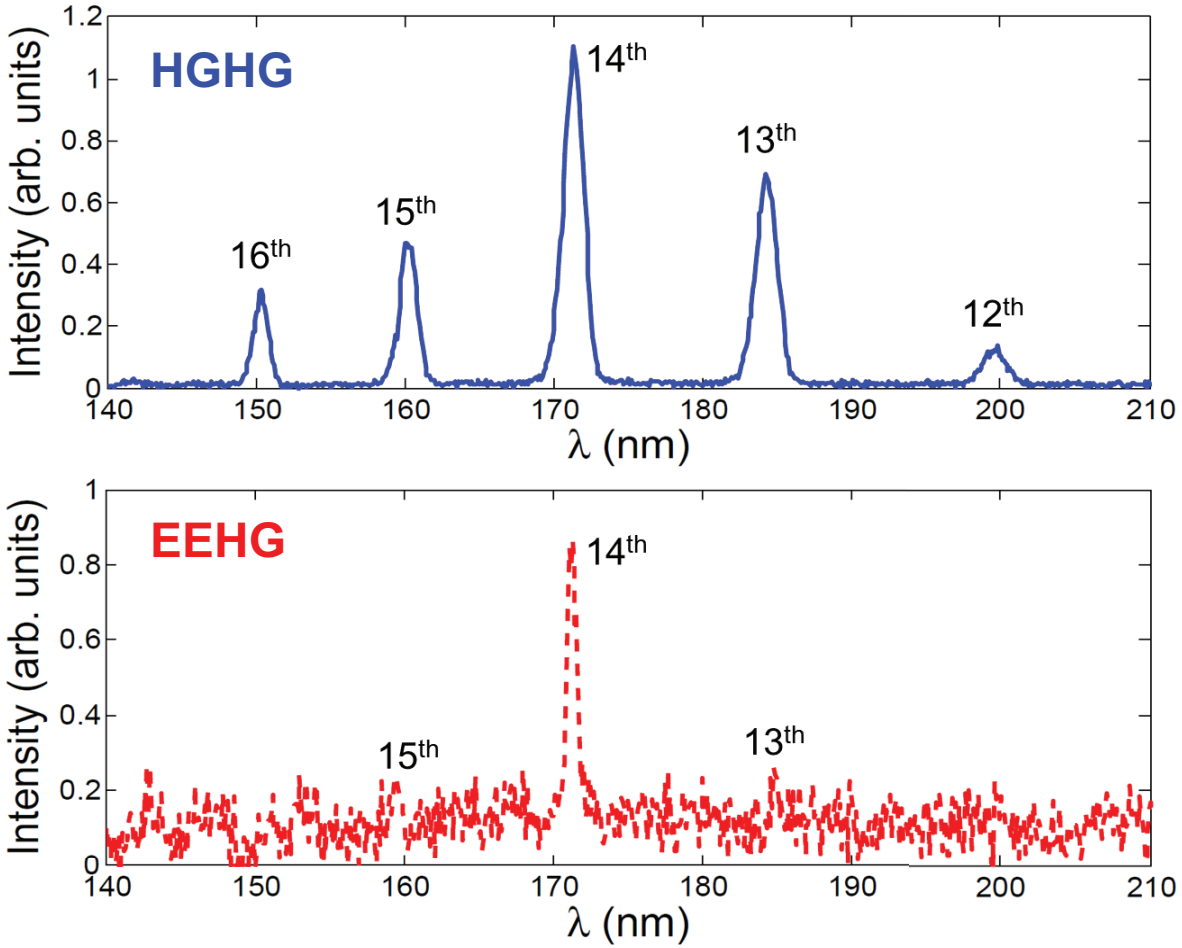


Demonstration of EEHG at the 14th harmonic

EEHG at the 14th harmonic

HGHG and EEHG signals

- $R_{56}^{(1)}$=5.91 mm, $R_{56}^{(2)}$=1.37 mm



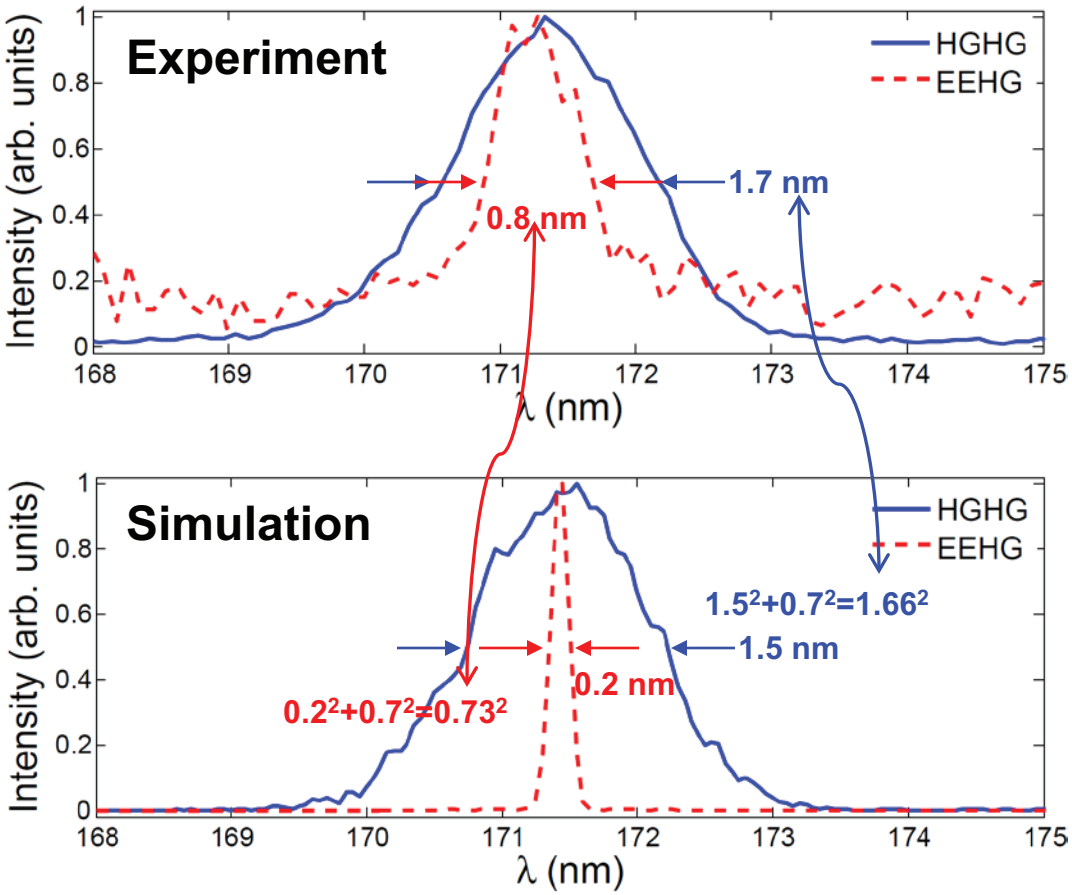
- HGHG signal is 10 times larger than EEHG
- EEHG has smaller bandwidth

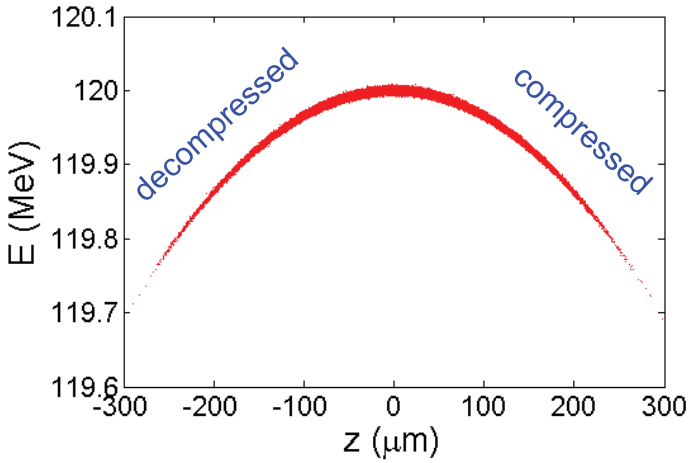
Demonstration of EEHG at the 14th harmonic

EEHG at the 14th harmonic

HGHG and EEHG signals

- $R_{56}^{(1)}$=5.91 mm, $R_{56}^{(2)}$=1.37 mm





Longitudinal phase space

- Resolution: 0.7 nm
- Δλ=1.7 nm for HGHG
- Δλ=0.8 nm for EEHG

Xiang *et al., PRL 105, 114801* (2010)

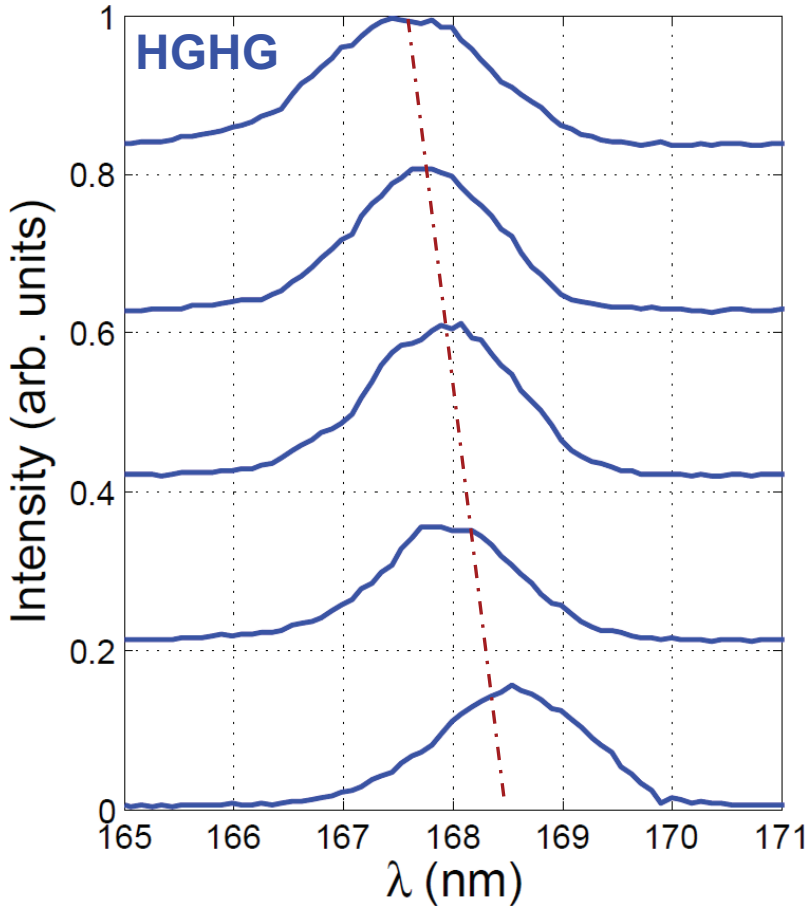
Zhao *et al., Nat. Photonics, 6, 360* (2012)

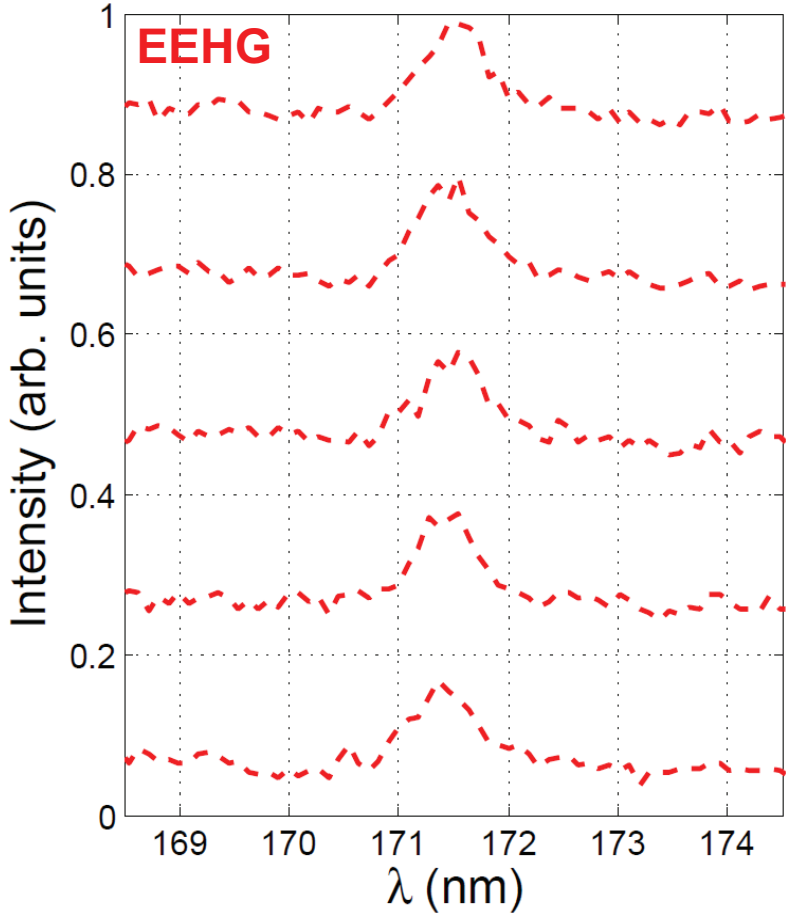
Demonstration of EEHG at the 14th harmonic

EEHG at the 14th harmonic

HGHG and EEHG signals in presence of rf phase drift

- $R_{56}^{(1)}$=5.91 mm, $R_{56}^{(2)}$=1.37 mm





Demonstration of EEHG at the 14th harmonic

Summary

- EEHG at the 14th harmonic has been demonstrated;
- Nearly transform-limited radiation at 170 nm has been produced with EEHG in presence of quadratic energy chirp;
- Understanding why EEHG signal is smaller than expected will be the focus of our work in the near future.

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This program would not have accomplished anything without the dedication from all the ECHO team members.

Thanks!