Shaping in a different way

Laboratoire Collisions Agrégats Réactivité

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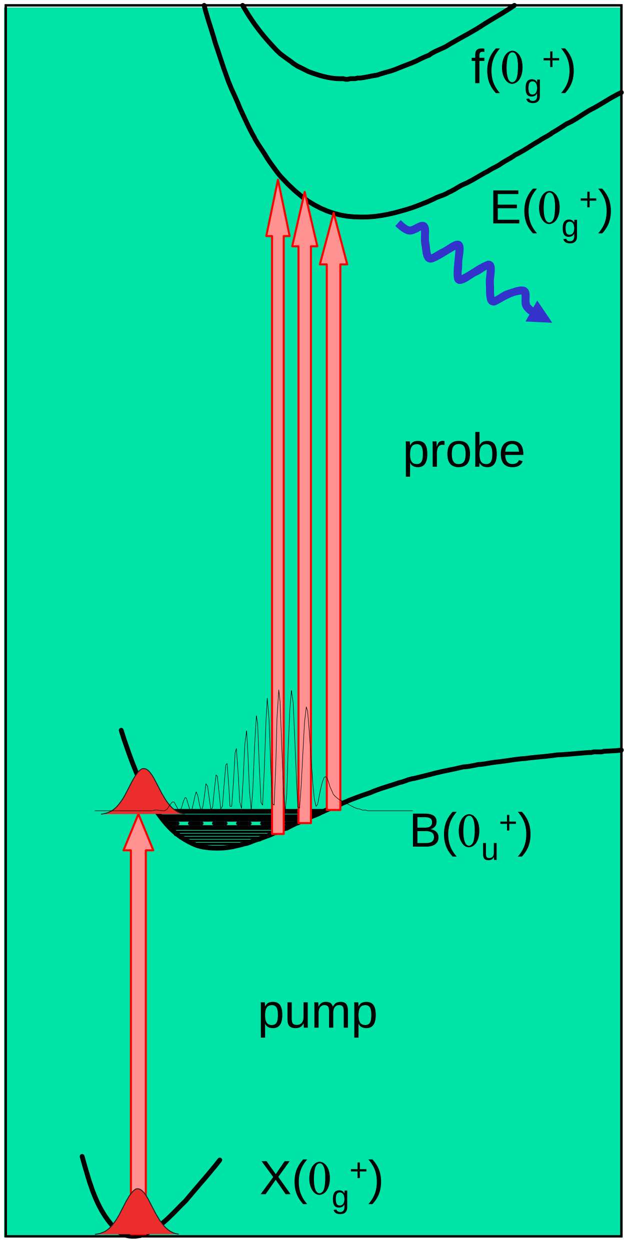
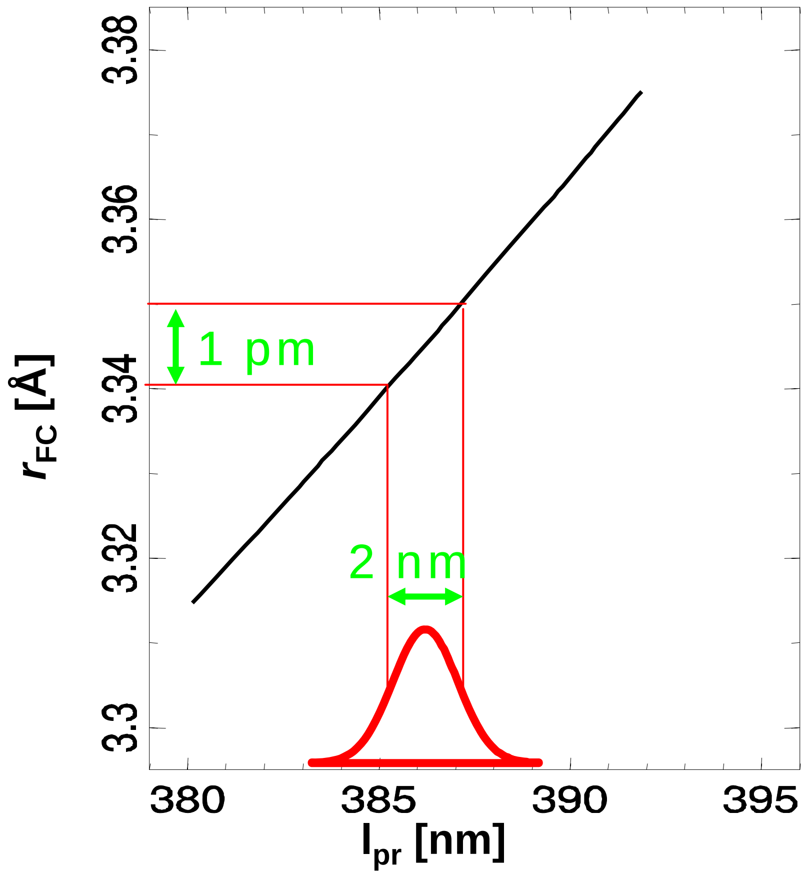
Menu

- Shaping the probe in a pump-probe experiment
- Factorization of numbers using Gauss sum.
- Shaping UV pulses using a new AOPDF device

The probe is so important!!



Probing wavepacket interferences in I_2 by scanning the probe wavelength



H. Katsuki, H. Chiba, B. Girard, C. Meier and K. Ohmori, Science **311**, 1589 (2006)

What's happen if the probe is shaped?

Some results have been obtained to emphasize the importance of the probe's wavelength

THE JOURNAL OF CHEMICAL PHYSICS **127**, 014312 (2007)

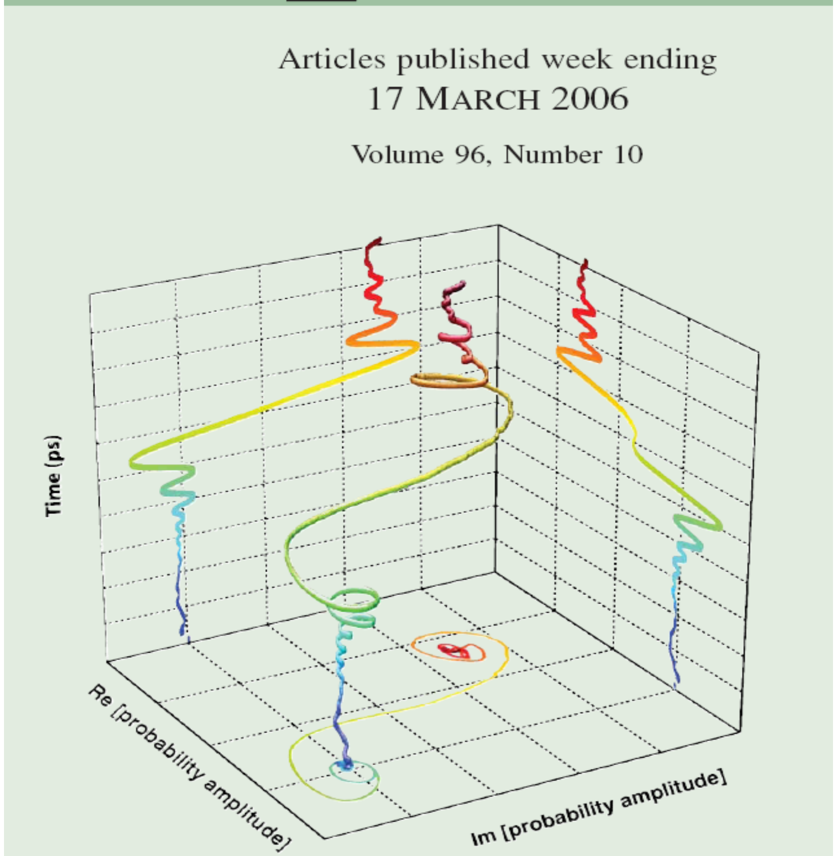
Control of wave packets in Li_2 by shaping the pump and probe pulses for a state-selected pump-probe analysis of the ionization continuum

Xingcan Dai and Stephen R. Leone[a)]
Department of Chemistry, University of California, Berkeley, California 94720; Department of Physics, University of California, Berkeley, California 94720; and Lawrence Berkeley National Laboratory, University of California, Berkeley, California 94720

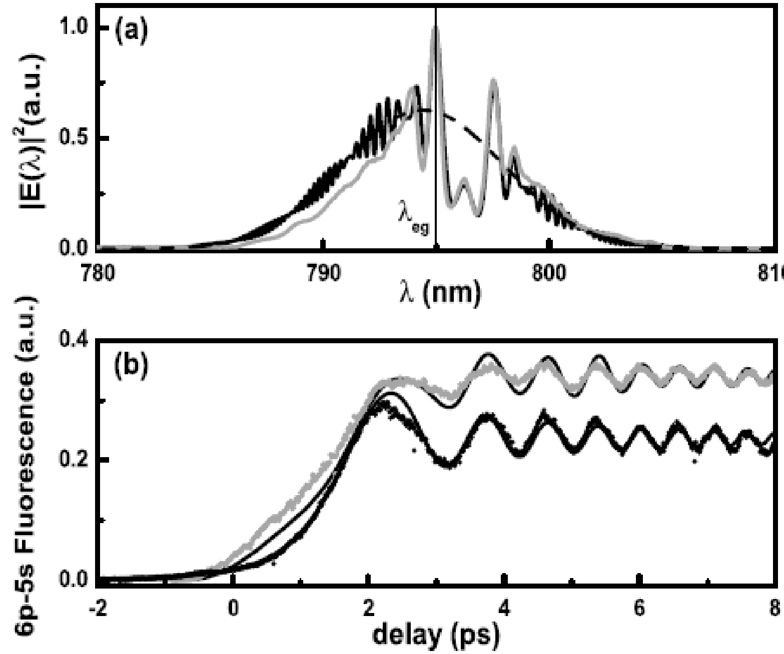
(Received 16 January 2007; accepted 8 May 2007; published online 5 July 2007)

→ **Shape the phase of the probe**

Quantum holography : to follow the wave function in real time



Monmayrant et al
PRL 96, 103002 (2006)



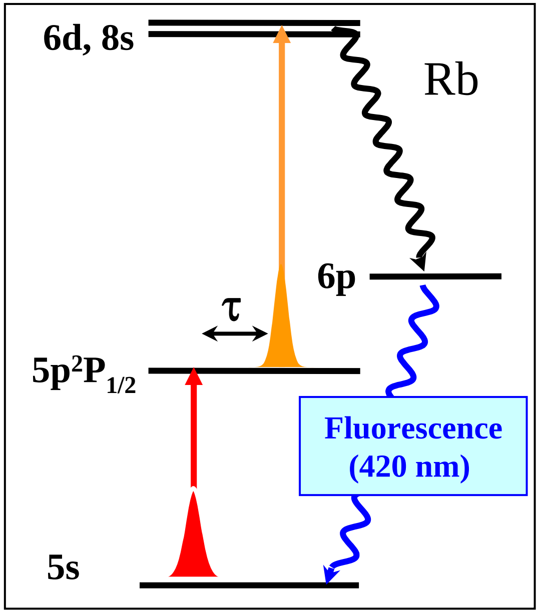
To implement Temporal Fresnel lens

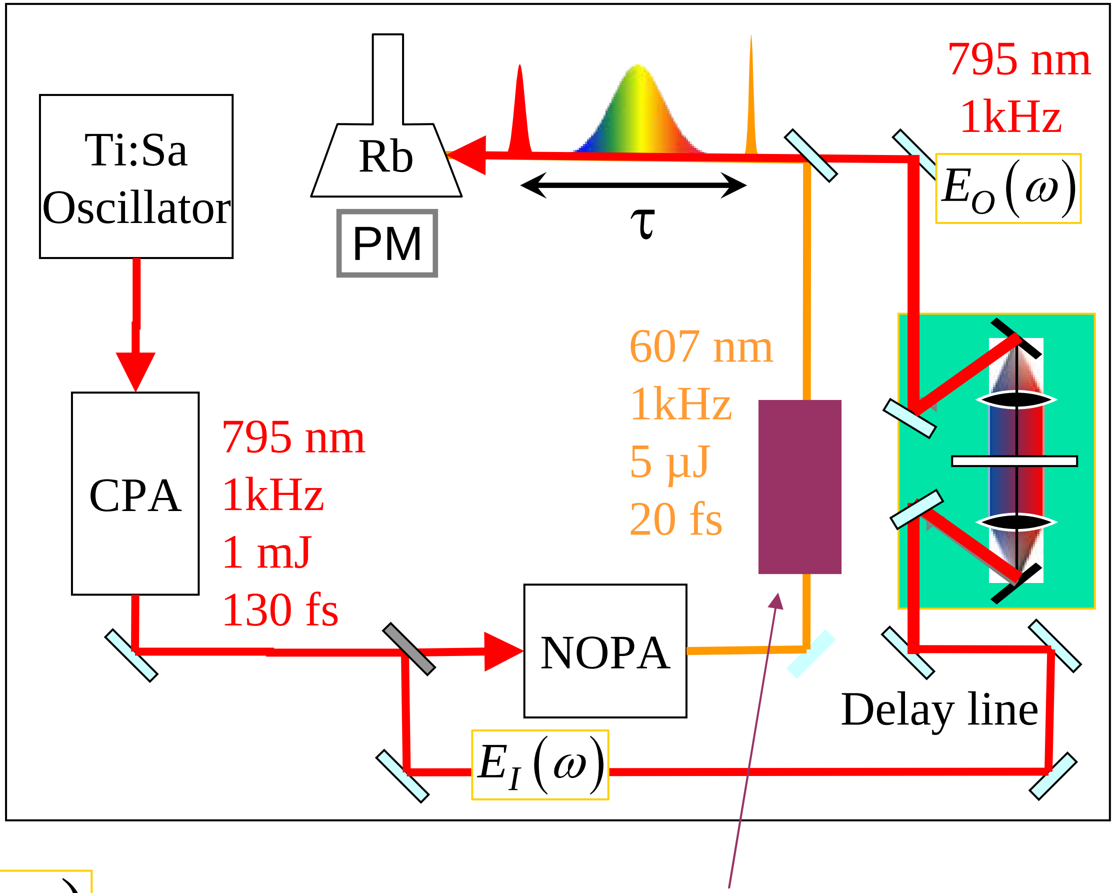
*Degert et al, PRL **89**, 203003-2 (2002)*

To use the coherence of the atom to reconstruct the electric field.

Monmayrant et al OL 31, 410 (2006)

Experimental Set-up

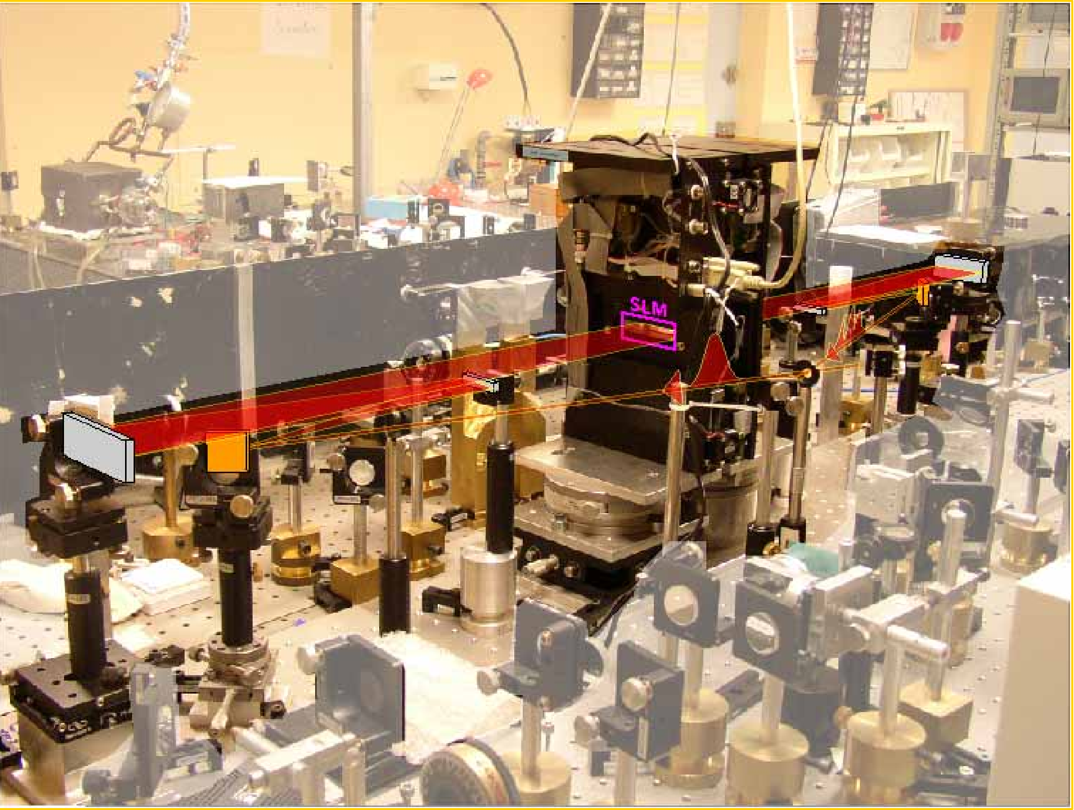


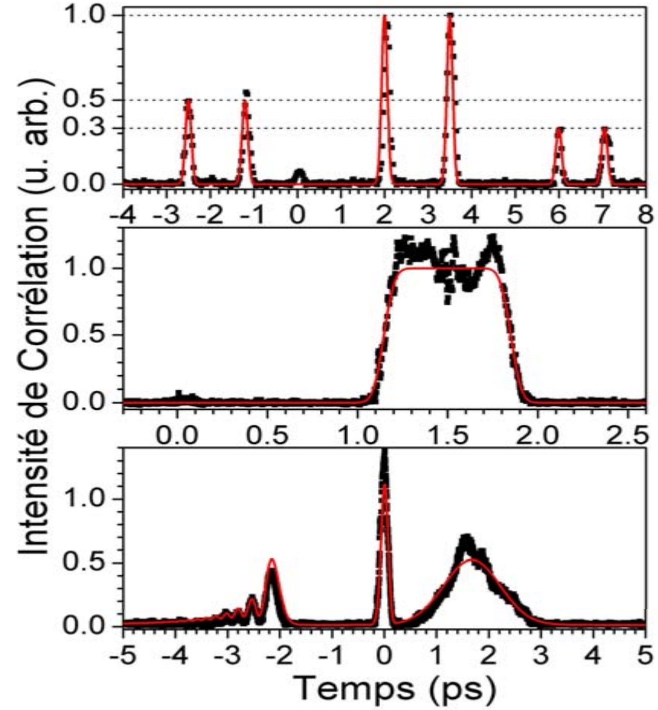


$$E_O(\omega) = H(\omega) E_I(\omega)$$

Grating's pair to chirp the probe.

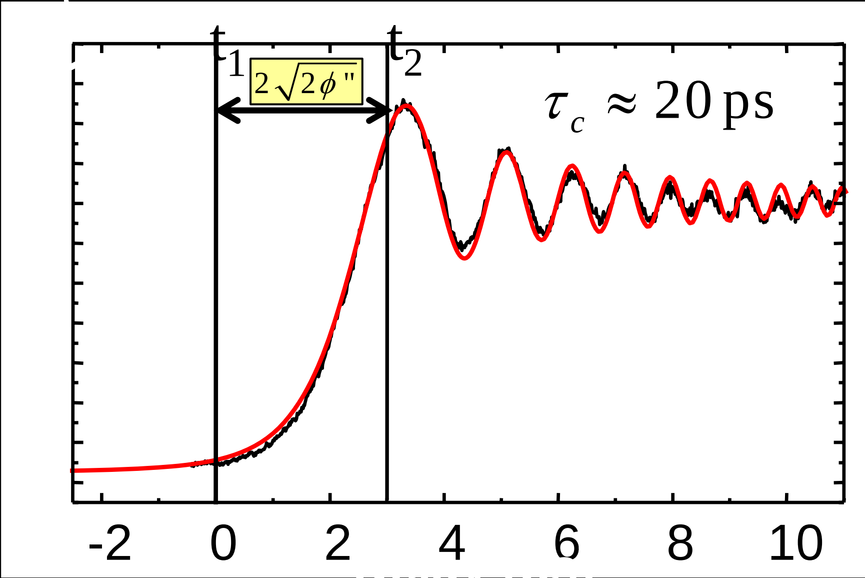
Our high resolution pulse shaper



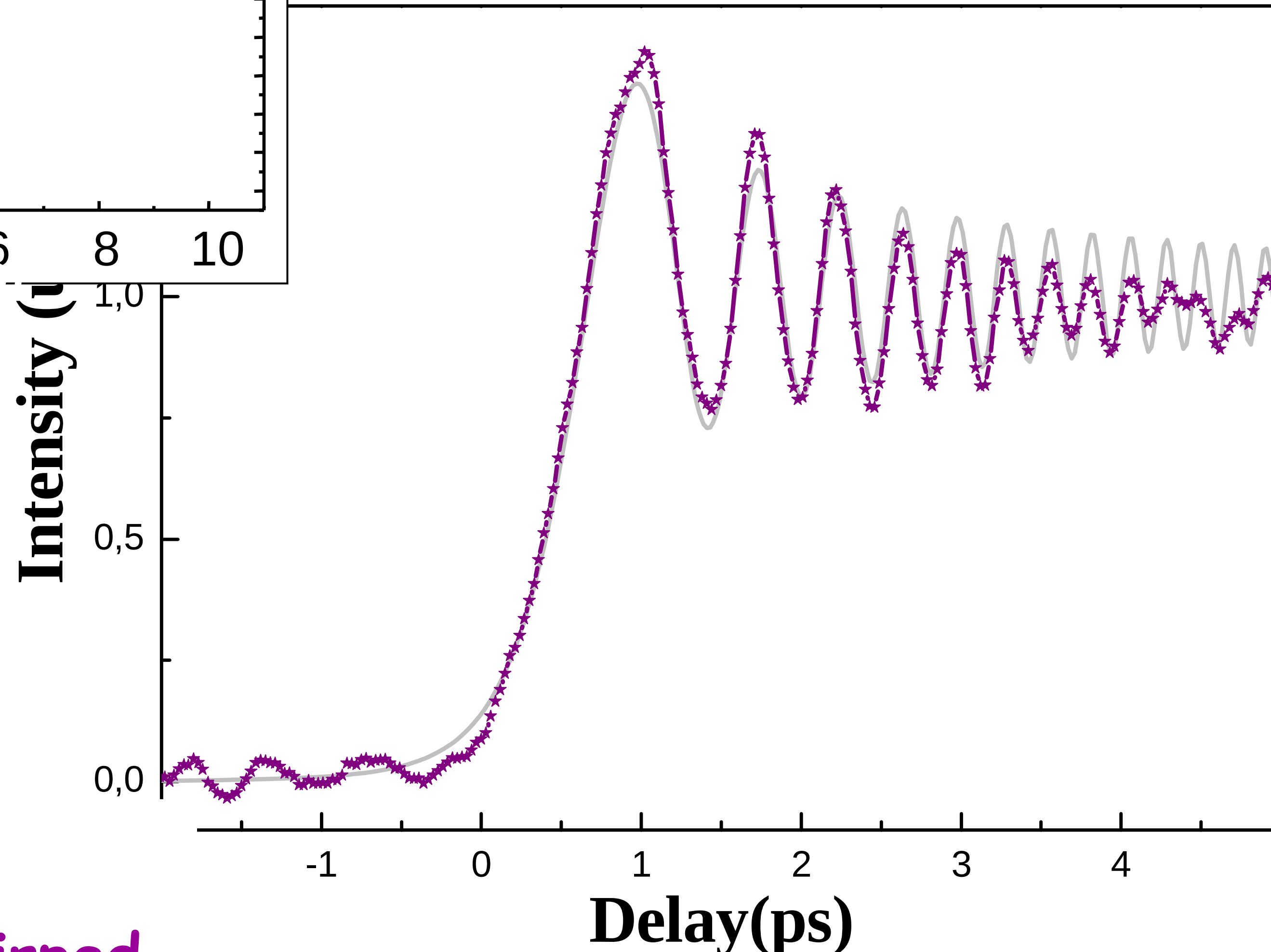


- Phase/Amplitude control over 640 pixels.
- shaping window of 35 ps.
- high complexity.
- high amplitude dynamic (30 dB).
- 75 % power transmission.

A. Monmayrant, B. Chatel. *"A new phase and amplitude **H**igh **R**esolution **P**ulse **S**haper."* ***Rev. Sci. Inst.*** **75,** 2668 (2004)



Pump strongly chirped/probe TF limited

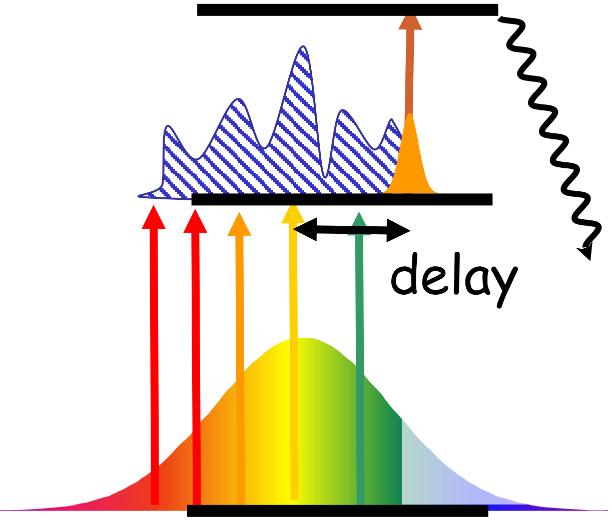


Pump TF limited

Probe strongly chirped

chirp=-1.4 10^5 fs^2

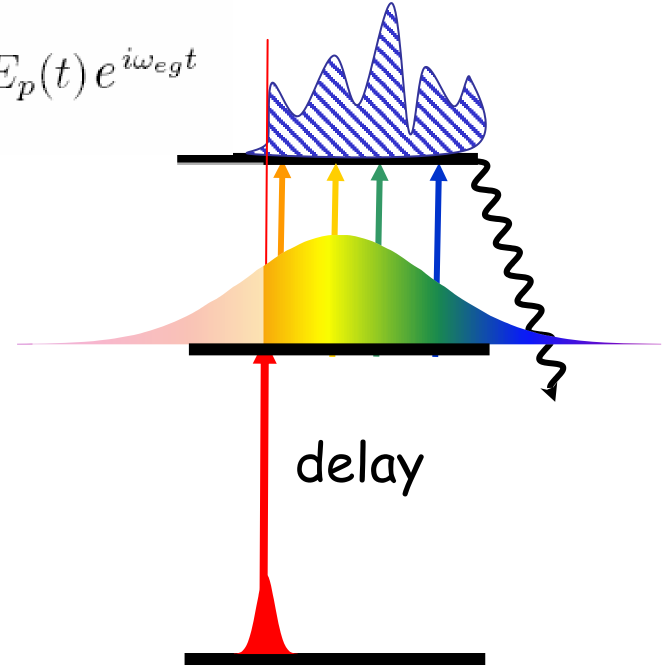
$$b_f(\tau) = -\frac{\mu_{fe}\mu_{eg}}{4\hbar^2}\int_{-\infty}^{\infty} dt' E_s(t') e^{i\omega_{fe}t'} \int_{-\infty}^{t'+\tau} dt E_p(t) e^{i\omega_{eg}t}$$



Chirped pump

Short probe

$$b_f(\tau) \propto \int_{-\infty}^{\tau} E_{pump}(t) e^{i\omega_{eg}t} dt$$



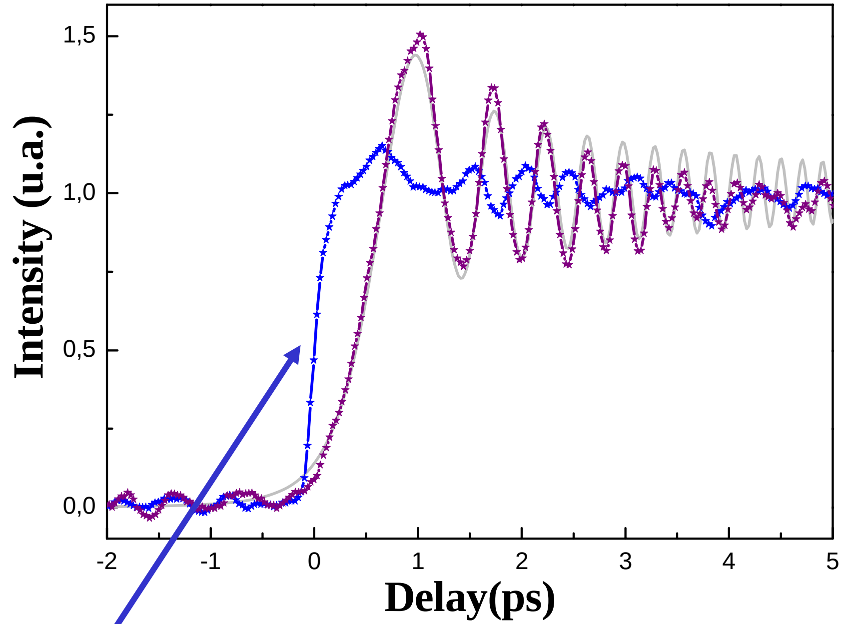
Short pump

Chirped probe

$$b_f(\tau) \propto \int_{\tau}^{+\infty} E_{probe}(t) e^{i\omega_{fe}t} dt$$

Analogy with the Fresnel diffraction : τ corresponds to the position of the sharp edge in the gaussian beam

What does it mean?



In this experiment

- Pump's duration :~12 ps
- Probe's duration :~14 ps

The rise time is less than 100 fs!!

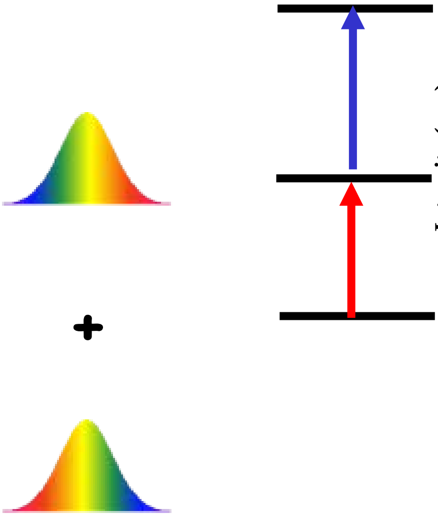
Interferences effect!

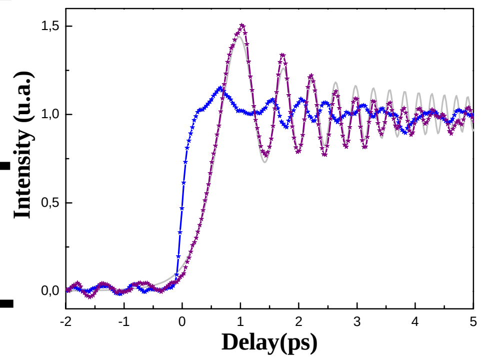
Mathematically :

$$\phi^{(2)}_{pump} = -\phi^{(2)}_{probe}$$

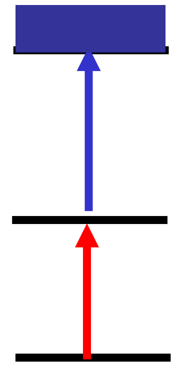
Does it mean that we can have access to a very short dynamic even the pump-probe are long?

Pump-probe experiment : a particular case of a two-photon transition



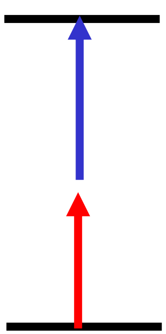


Short rise time



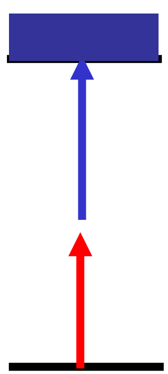
Work in progress :
Long rise time (averaging on the whole spectrum)
Short rise time (by filtering the photoe spectrum)

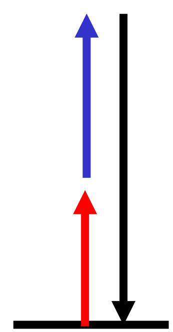
Behavior as a function of the pump-probe delay?



TPA

?





SFG-SHG

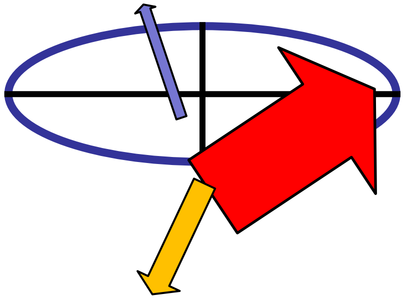
Generation of a ps pulse

(Raoult et al,OL 1998)

Menu

- Shaping the probe in a pump-probe experiment
- Factorization of numbers using Gauss sum.
- Shaping UV pulses using a new AOPDF device

What is a Gauss sum?

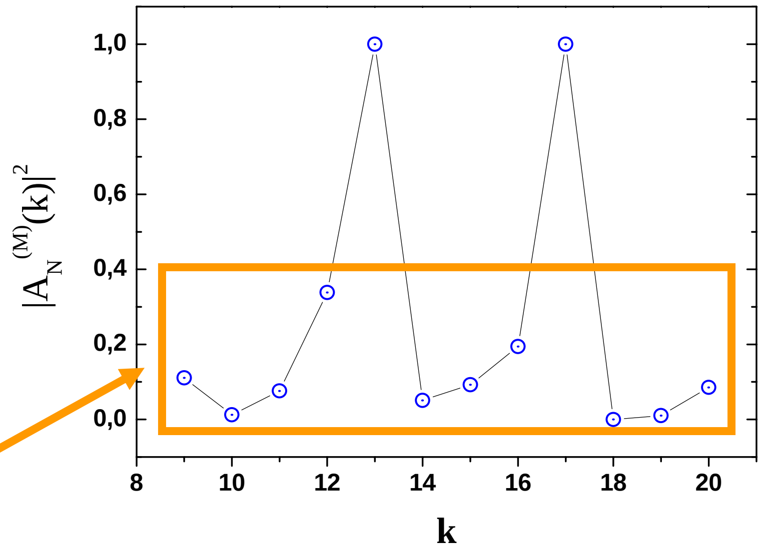


$$A_N^{(k)}(k) = \sum_{m=0}^{k-1} \rho_m \exp\left[2i\pi m^2 \frac{N}{k}\right]$$

$k \equiv$ Not a factor of N

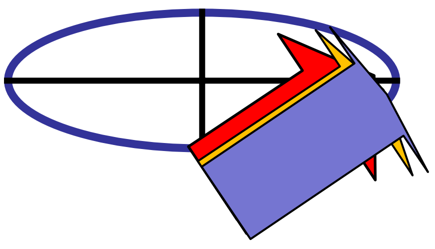
$$\frac{N}{k} \equiv \text{non-integer}$$

Phases oscillate rapidly with m



Factorisation of N=221=13*17

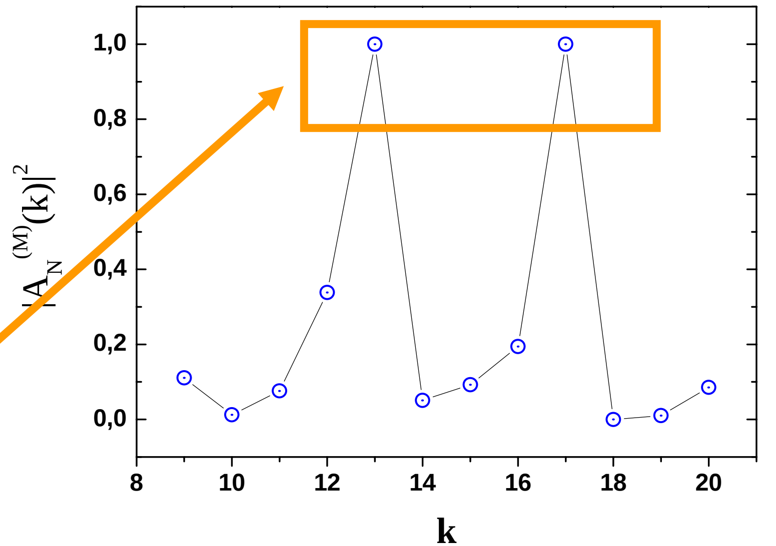
What is a Gauss sum?



$$A_N^{(k)}(k) = \sum_{m=0}^{k-1} \rho_m \exp\left[2i\pi m^2 \frac{N}{k} \right]$$

$$k \equiv \text{Factor of } N$$

$$\frac{N}{k} \equiv p \text{ (integer)}$$



Factorisation of N=221=13*17

$$A_N(k) = \sum_{m=0}^{M-1} \rho_m \exp\left[2i\pi m^2 p \right] = \sum_{m=0}^{M-1} \rho_m = 1$$

In practice : truncated Gauss sum

$$A_N(k) = \sum_{m=0}^{M-1} \rho_m \exp\left[2i\pi m^2 \frac{N}{k} \right]$$

The first few terms are enough to discriminate factors from non-factors (*W.P. Schleich et al*)

M is the order of the truncation and could be adjusted.

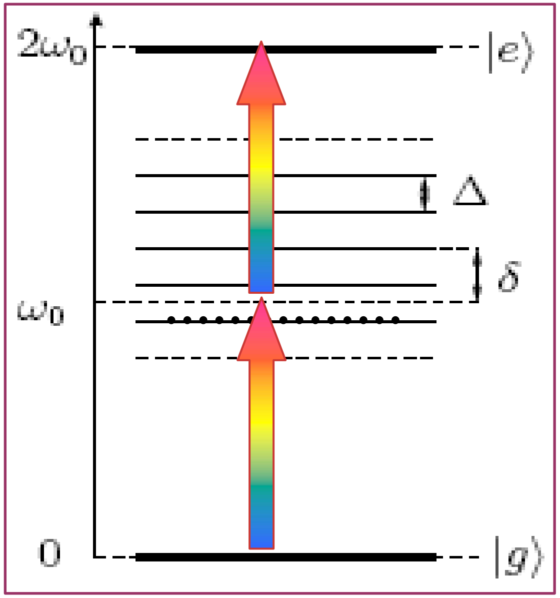
Many theoretical and experimental results

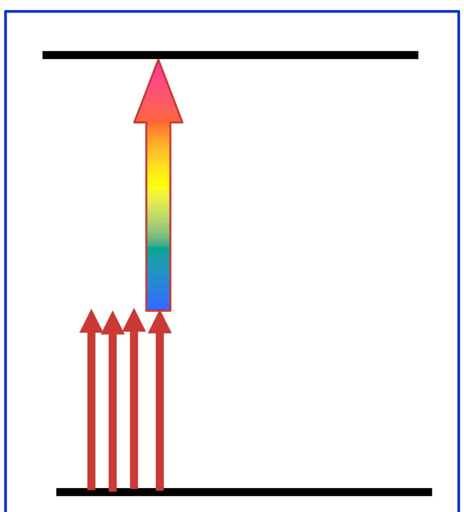
- Theory :
  - Merkel et al, Fortschr. Phys. 54, 856 (2006)
- NMR :
  - Mehring et al, Phys. Rev. Lett. 98, 120502(2007)
  - Mahesh et al, Phys. Rev. A 75, 062303(2007)
- Cold atoms:
  - Gilowski et al, Phys. Rev. Lett. **100** (2008)
- Our results with ultrashort pulses
  - Bigourd et al, Phys. Rev. Lett. **100**, 030202 (2008)
  - Weber et al, Eur. Phys. Lett (2008)

In all these experiments, the terms of the sum are precalculated....

Challenge : to find a physical system in which the Gauss sum will be calculated « automatically » for all values of k **between 2 and** $\sqrt{N}$ **sequentially or in parallel**

Our proposition using ultrashort pulses





- Several candidates :
  - Two-photon transition using chirped pulses
  - Sum frequency between a pulse train and a chirped pulse

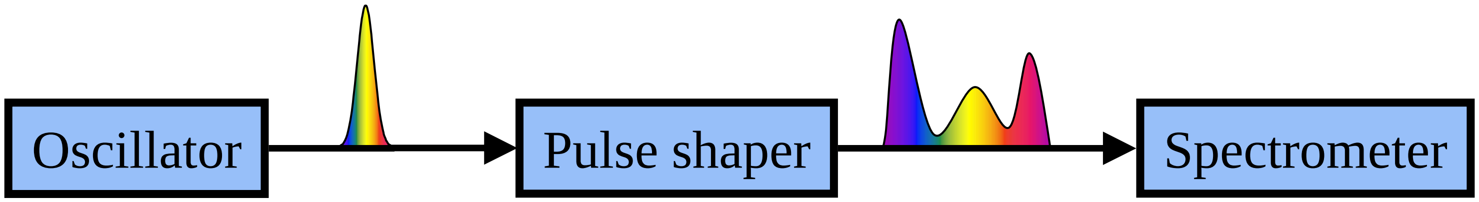
  Experimentally difficult to implement at the moment

- First step :
  An all optical experiment

First step : An all optical experiment

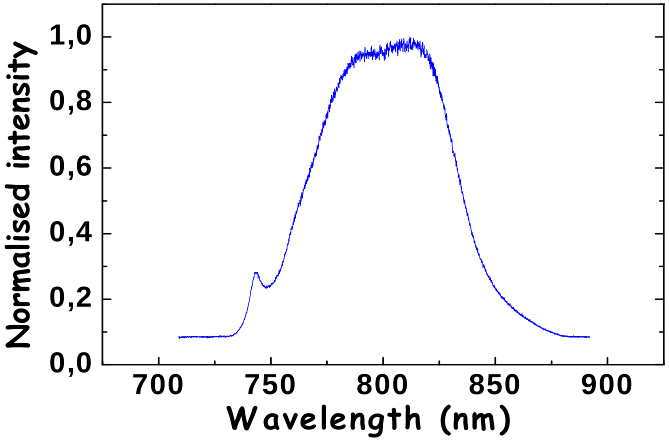
A pulse train with carefully chosen relative phases….

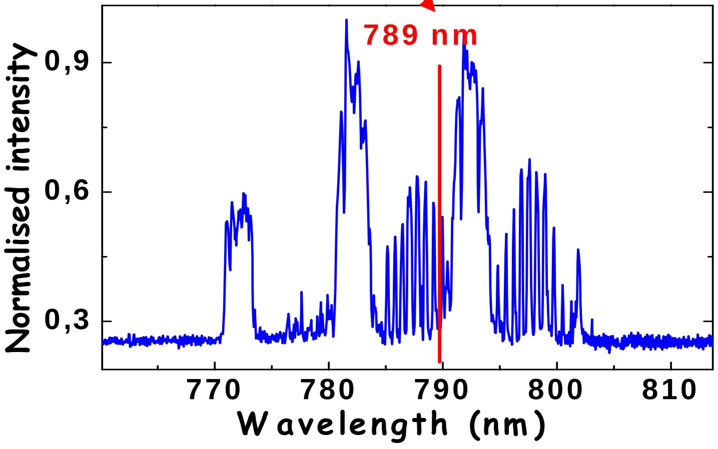
10 fs
800nm
80MHz



$$H(\omega) = \sum_{m=0}^{M-1} \exp\left[i\theta_m + i\, m\, \phi^{(1)}(\omega - \omega_p) \right]$$

$$\theta_m = 2\pi m^2 \frac{N}{k} \qquad \text{with } \phi^{(1)} = 200 \text{ fs}$$

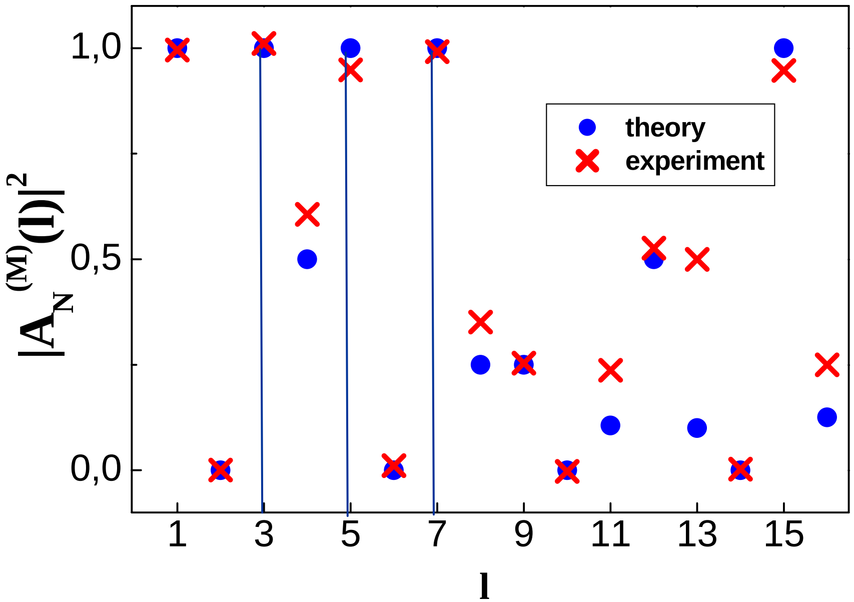




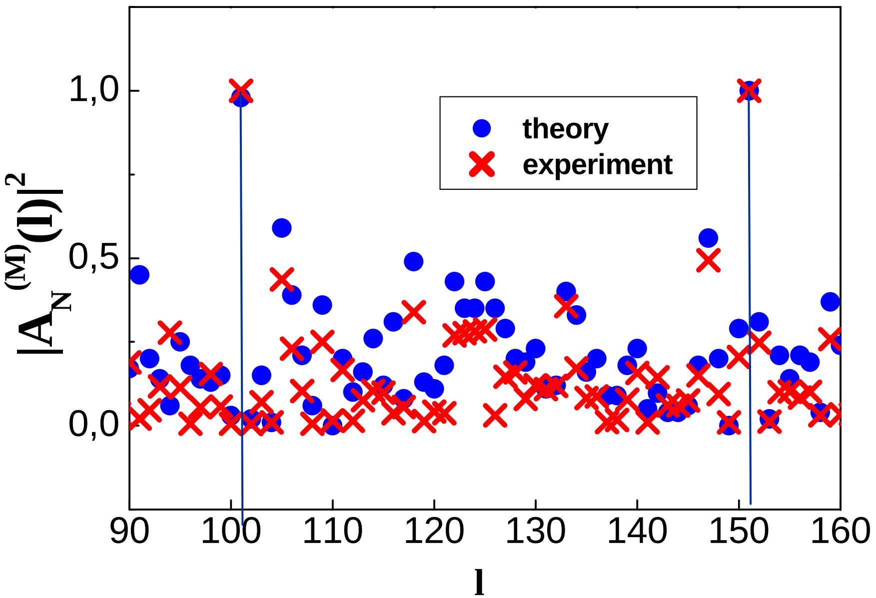
First results

Good agreement between experiment and theory:

N=105=3*5*7   4 pulses



N=15251=101*151   9 pulses



Factorization of Numbers with the temporal Talbot effect: Optical implementation by a sequence of shaped ultrashort pulses
D. Bigourd, B. Chatel, W. P. Schleich, B. Girard, PRL (2008)

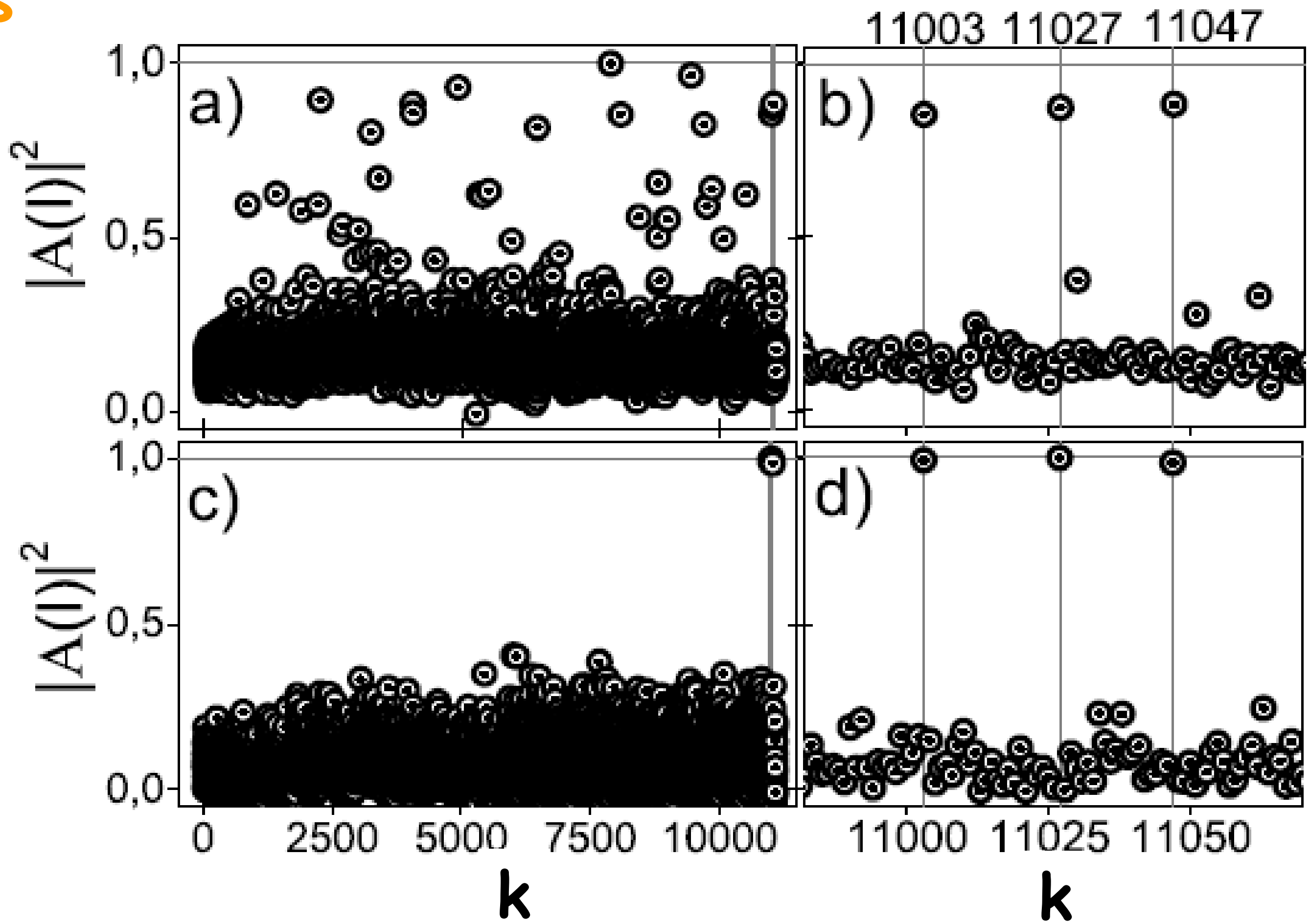
Experimental Results

N=1'340'333'404'807
=11003*11027*11047

30 pulses

Sequential

Random



Factoring numbers with interfering random waves.

S. Weber, B. Chatel and B. Girard, EPL 2008.

Shaping between 200nm and 400nm

- Using a new AOPDF device in the UV (see Kaplan's talk). Main limitation : only 12% of the energy on the shaped pulse (50% absorption+ diffraction efficiency).
- Using cross-correlation technique by difference frequency mixing
- Using two-photon absorption in the diamond as a characterization tool

Conclusion

- Shaped probe : Coll with P. Salières (Saclay) to implement an experiment with HH
- Factorization :To find a system which calculates directly the Gauss sum
- Shaping and Characterization in the UV :To improve our device, to compare with a new device using MEMS recently developped by J.P. Wolf (Geneva)

LOOKING for a phD student (FASTQUAST)