Femtosecond pulse shaping for coherent control of gold nanoparticles formations

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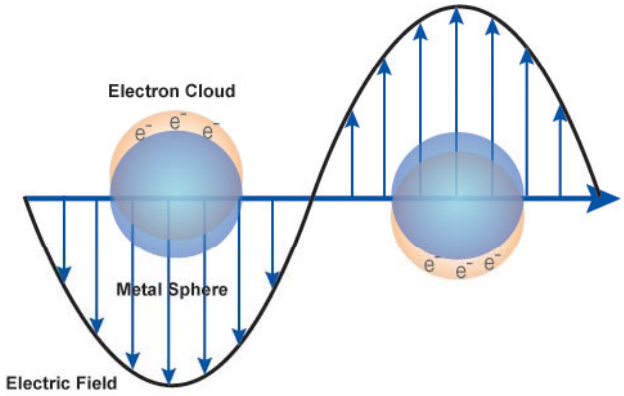
Outline

- Motivation
- Coherent control
- Pulse shaper
- Results on the control of nanoparticles formation
- Conclusions

Nanoparticles

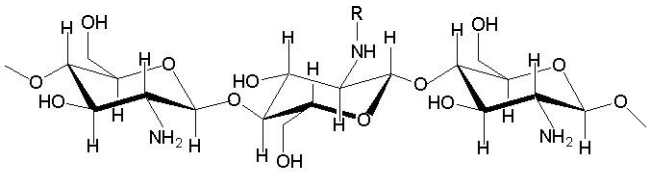
diameter 1-100 nm

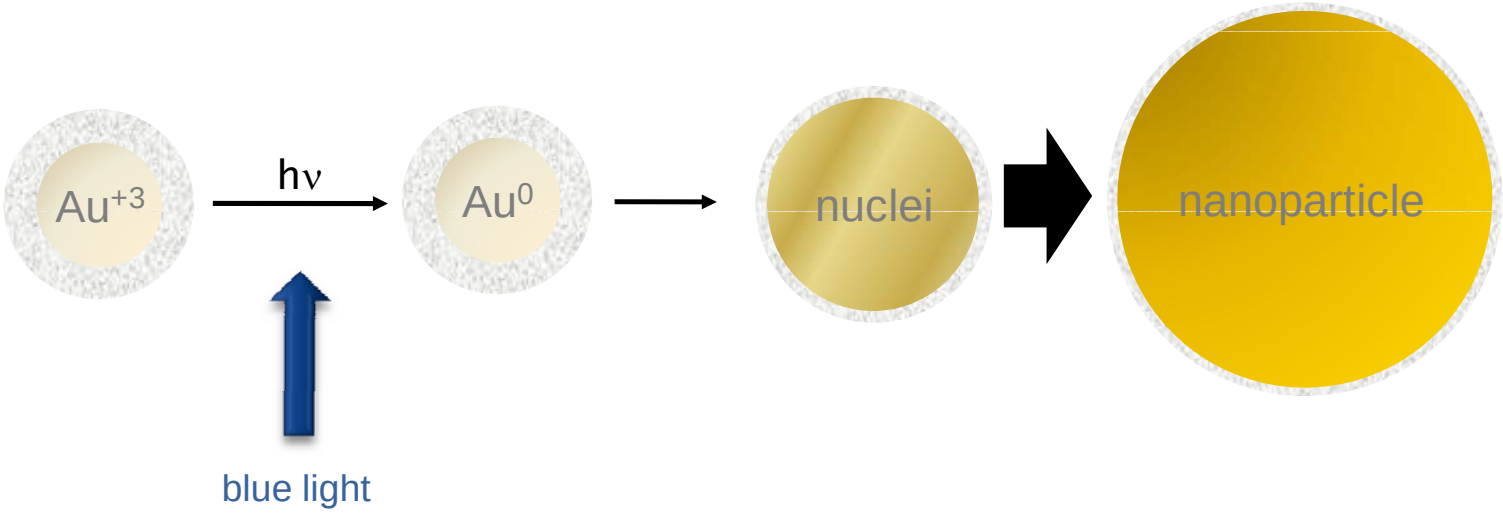


- Plasmon resonance
- Enhancement of optical processes
- Synthesis
  - chemical reduction
  - photo-reduction

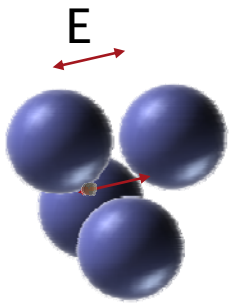
Photo-reduction

$HAuCl_4$ + chitosan



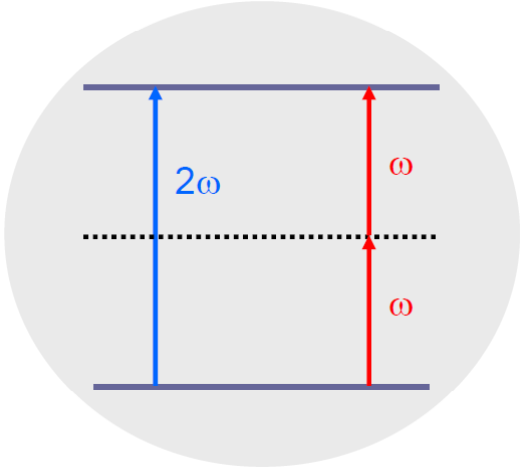


Two-photon absorption



high intensity

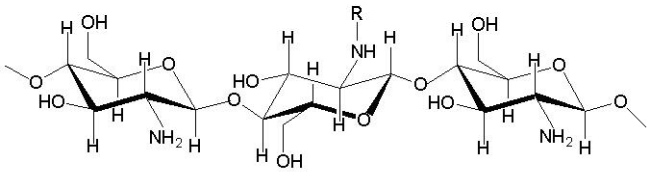
$$P = \chi^{(1)}E + \chi^{(2)}E^2 + \chi^{(3)}E^3 + \ldots$$

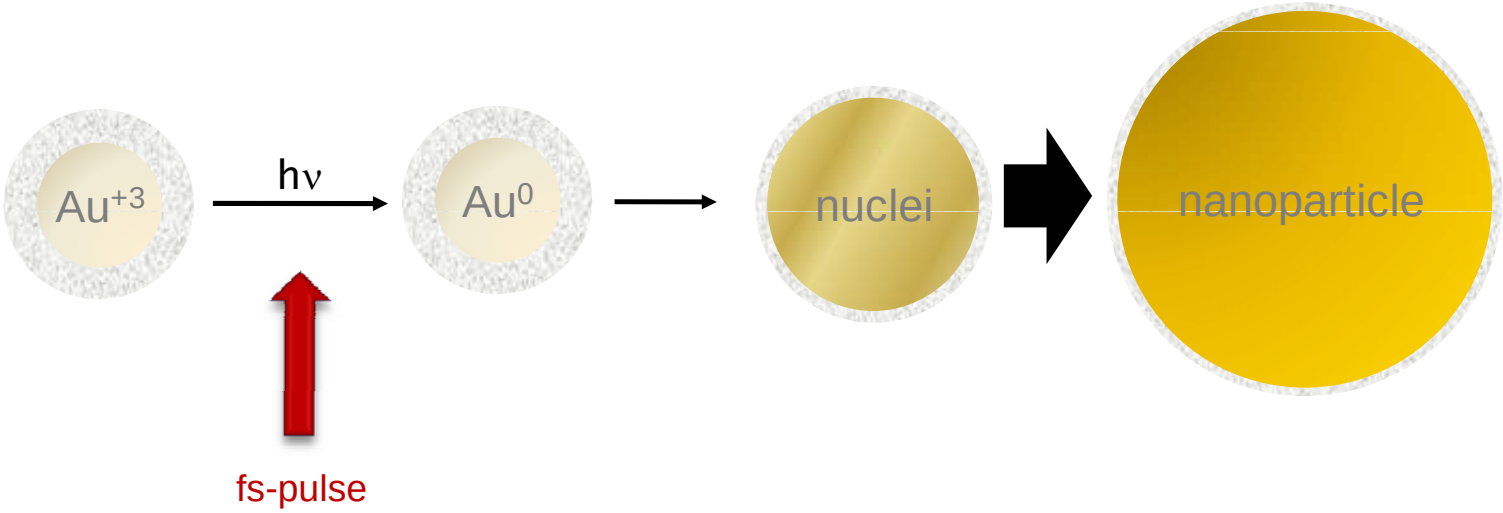


$$\alpha = \alpha_0 + \beta I$$

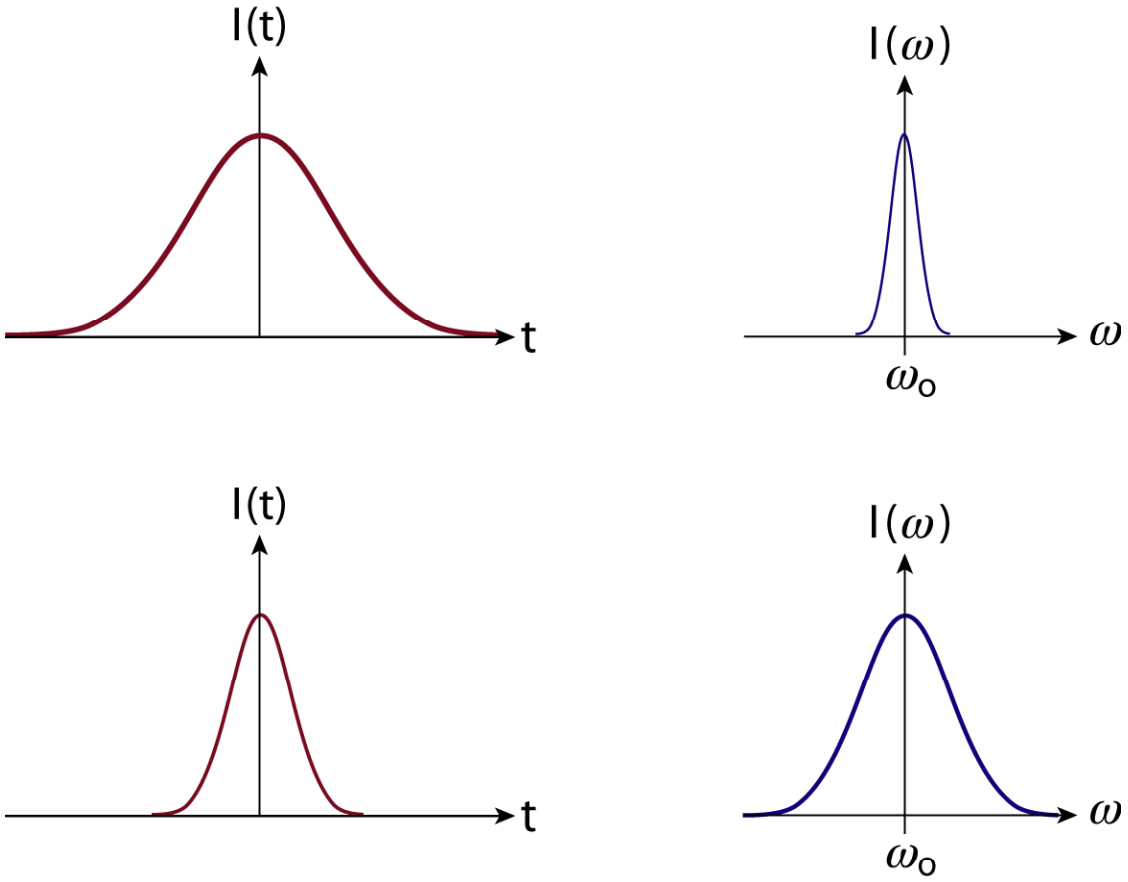
Photo-reduction

$HAuCl_4$ + chitosan





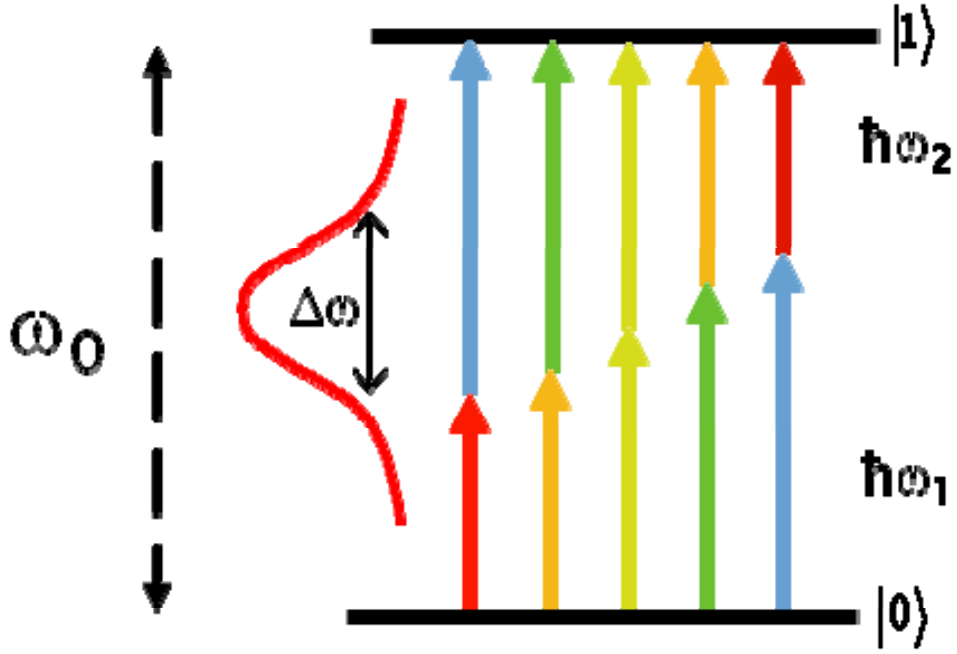
Ultrashort pulses



broad spectral band

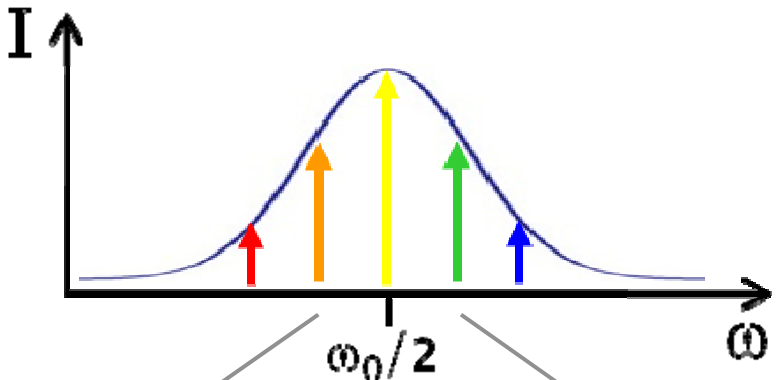
allows spectral control of the nonlinearity

Coherent control



$\varphi(\omega)$ spectral phase

Coherent control

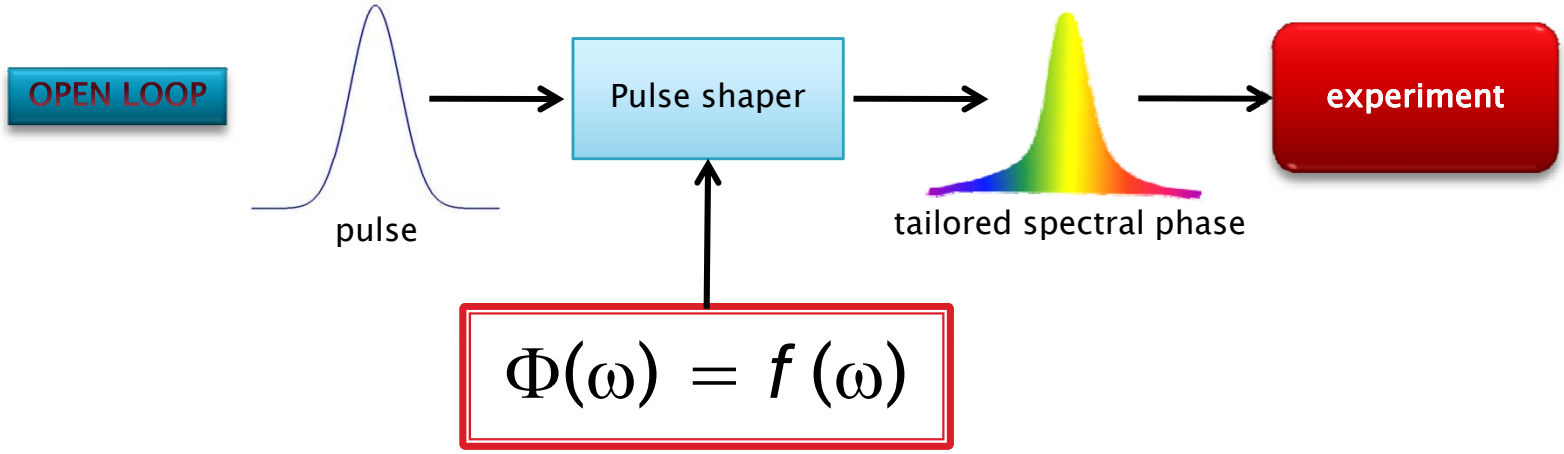


$$E_1 = A(\omega_0/2+\Omega)e^{-i\varphi(\omega_0/2+\Omega)} \qquad E_2 = A(\omega_0/2-\Omega)e^{-i\varphi(\omega_0/2-\Omega)}$$

two-photon absorption probability

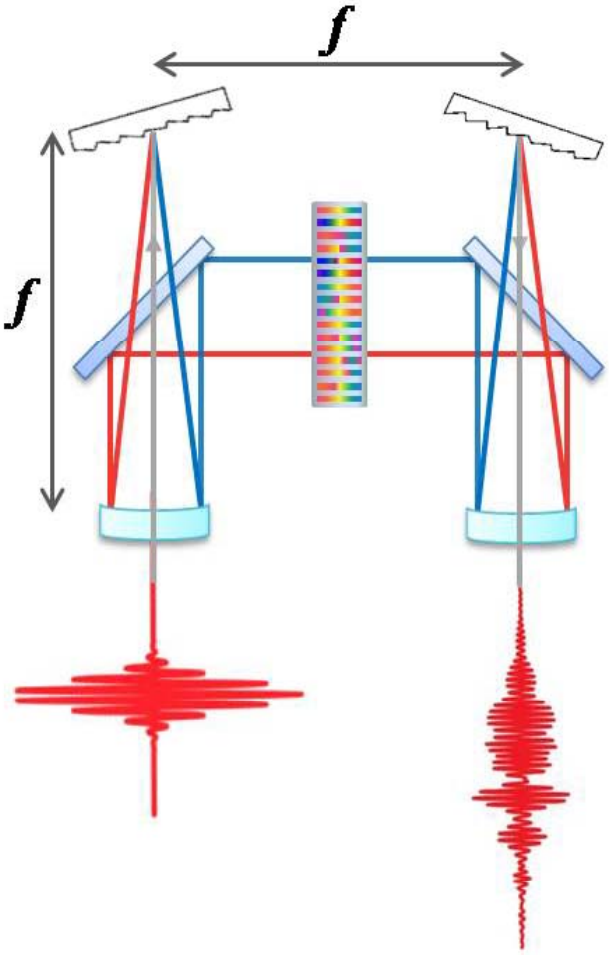
$$S_2(\omega_0) \propto \left| \int_{-\infty}^{+\infty} A(\omega_0/2+\Omega)A(\omega_0/2-\Omega) \cdot \exp\{i\,[\varphi(\omega_0/2+\Omega)+\varphi(\omega_0/2-\Omega)]\}\, d\Omega \right|^2$$

Coherent control

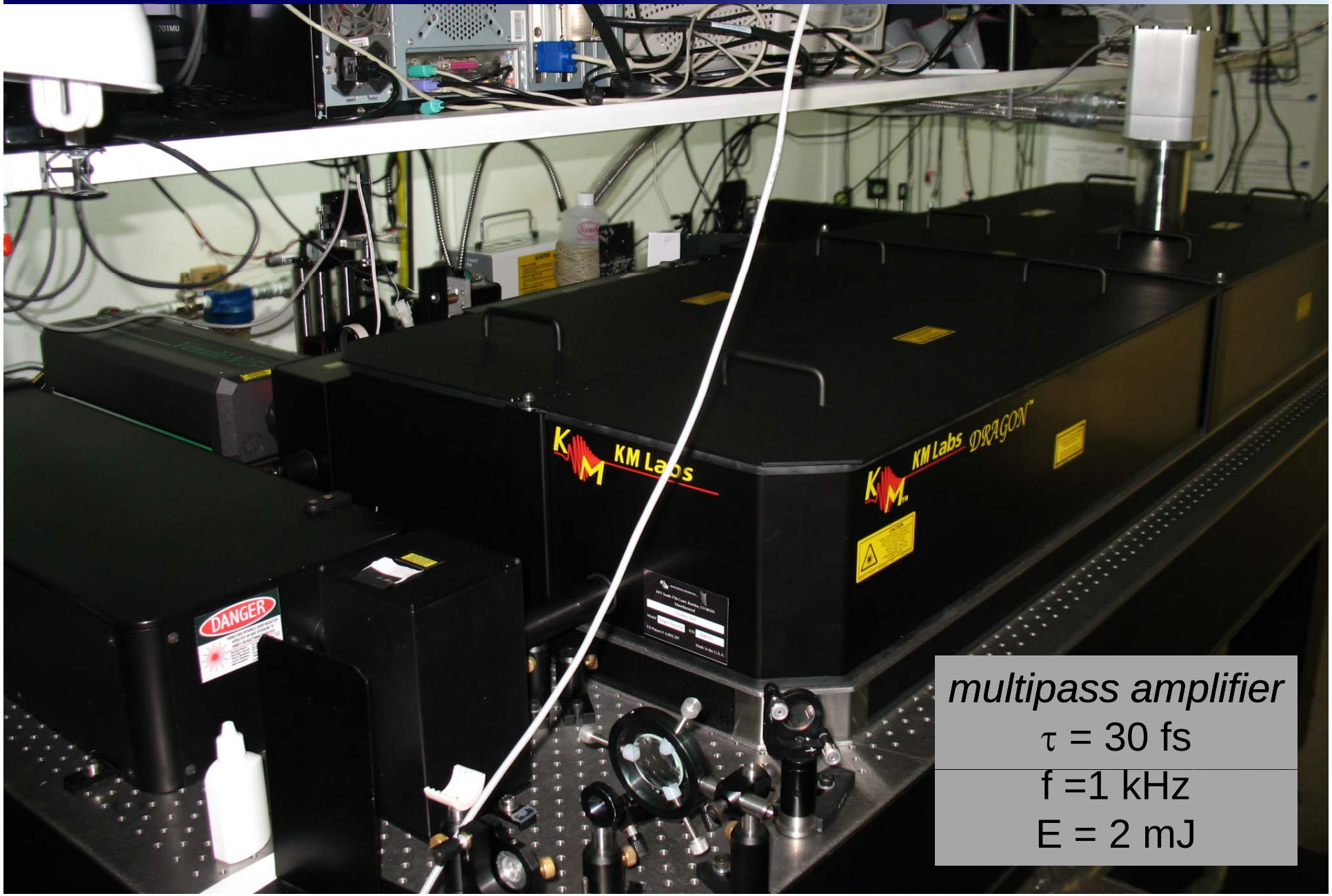


Pulse shaper

4f configuration



Amplified laser system



multipass amplifier

τ = 30 fs

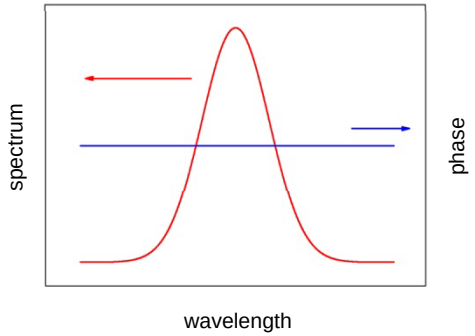
f =1 kHz

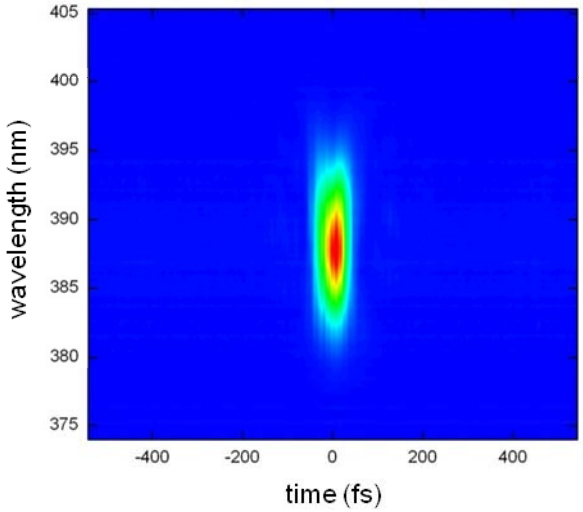
E = 2 mJ

Results

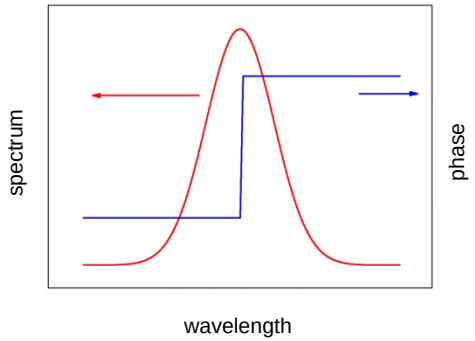
FROG traces of the pulses

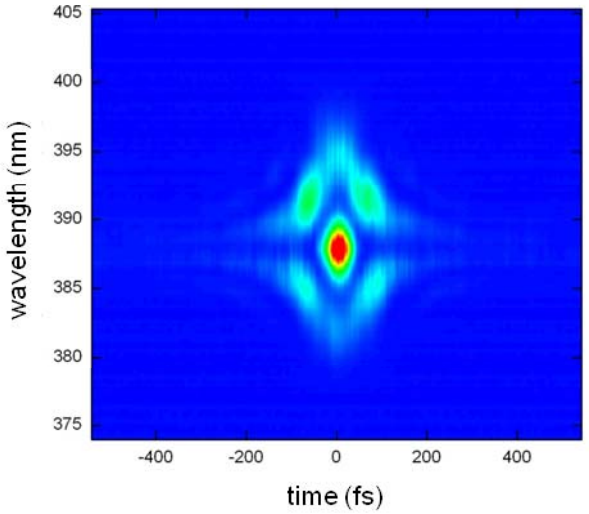
FTL





step

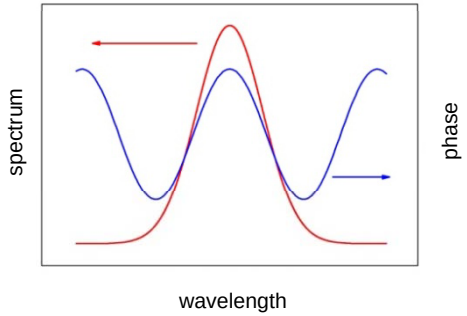


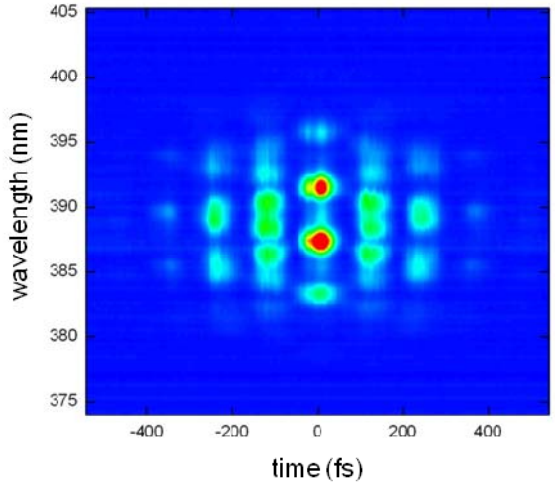


Results

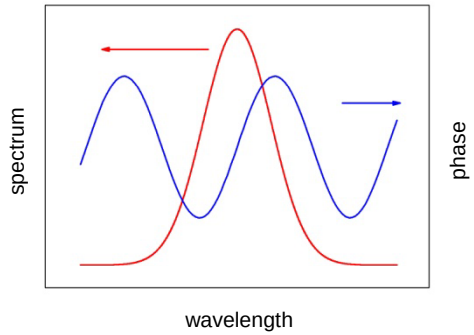
FROG traces of the pulses

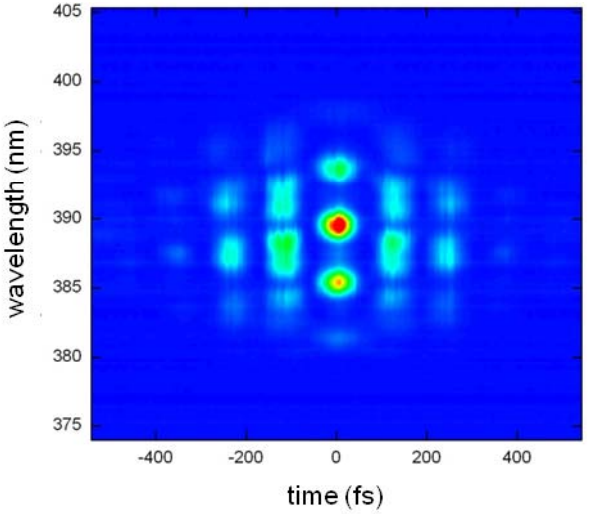
cosine



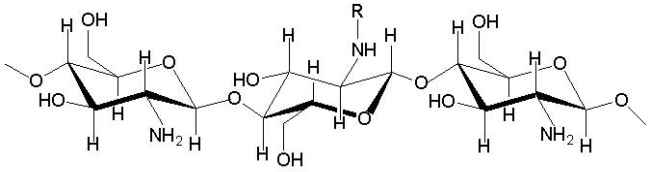


sine





Results

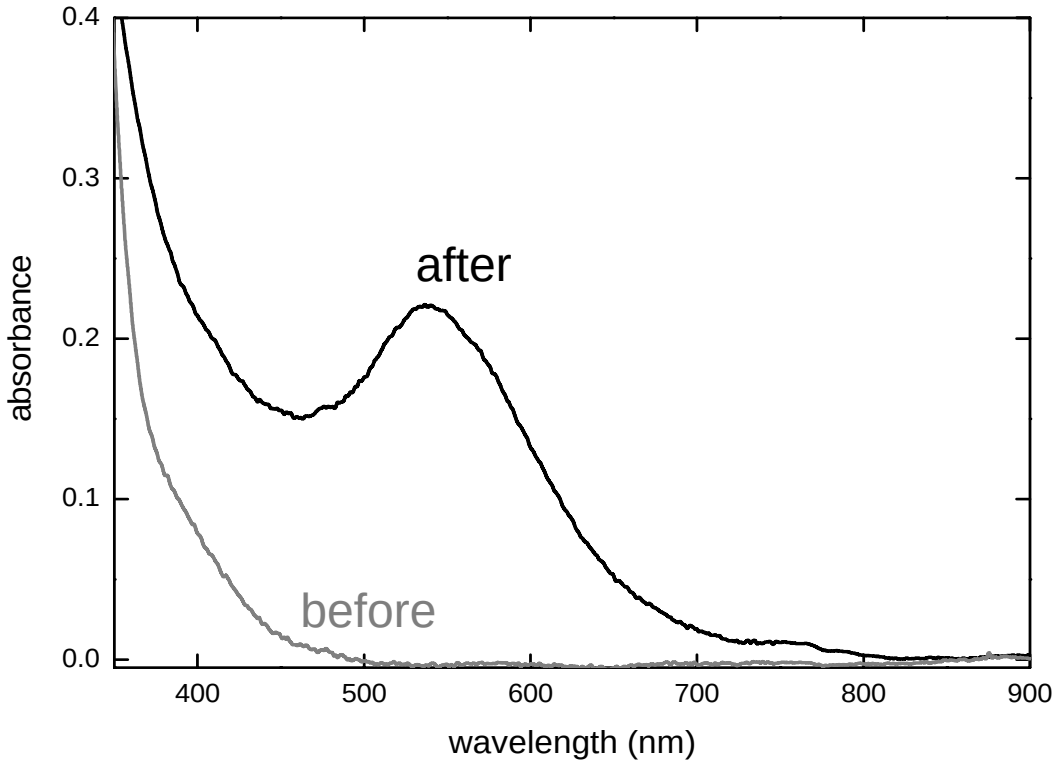


+ $HAuCl_4$

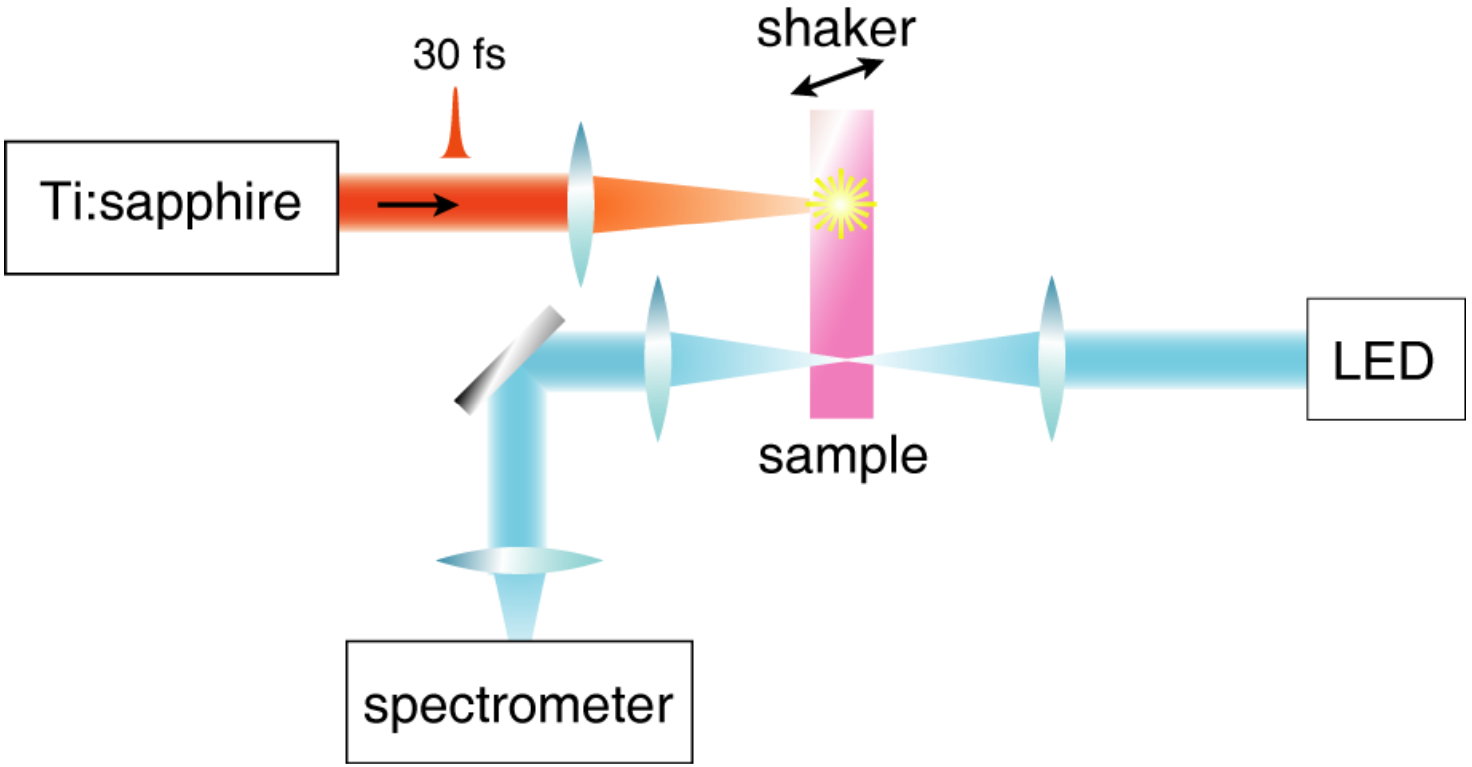
two-photon induced photoreduction

FTL

E = 185 μJ



Results

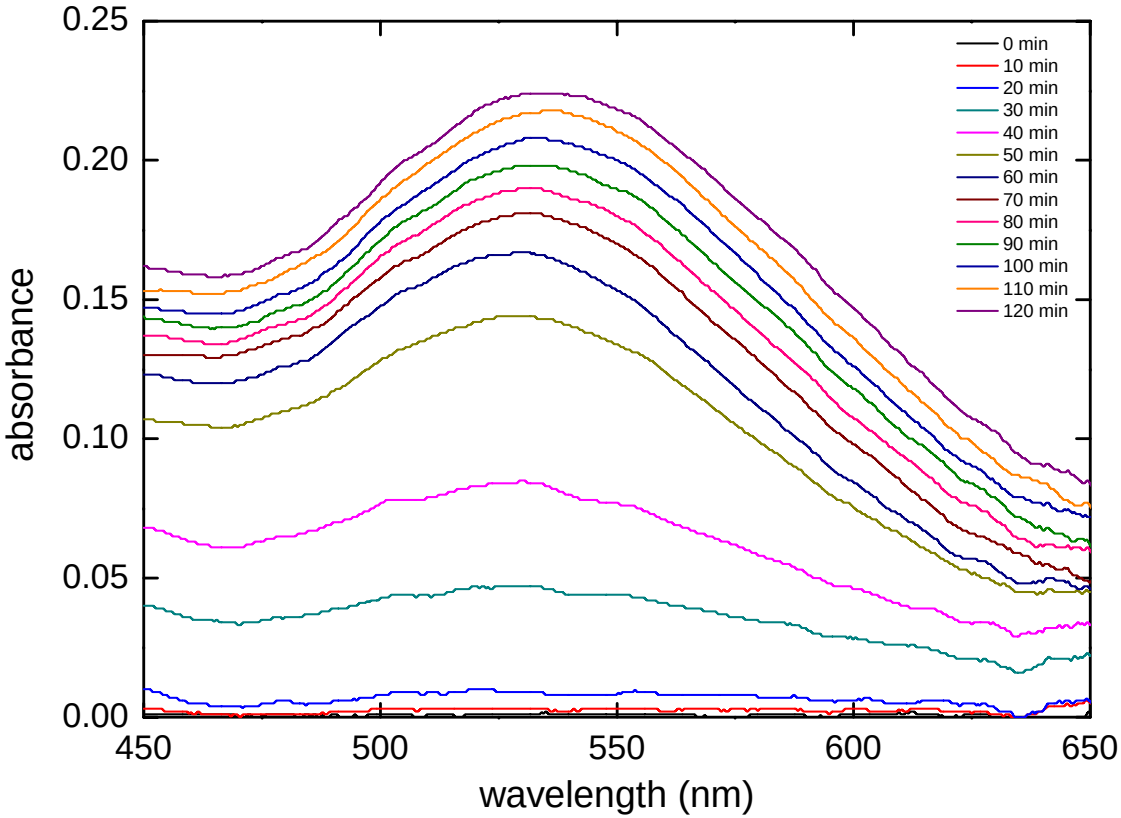


to measure the dynamics of nanoparticles formation

Results

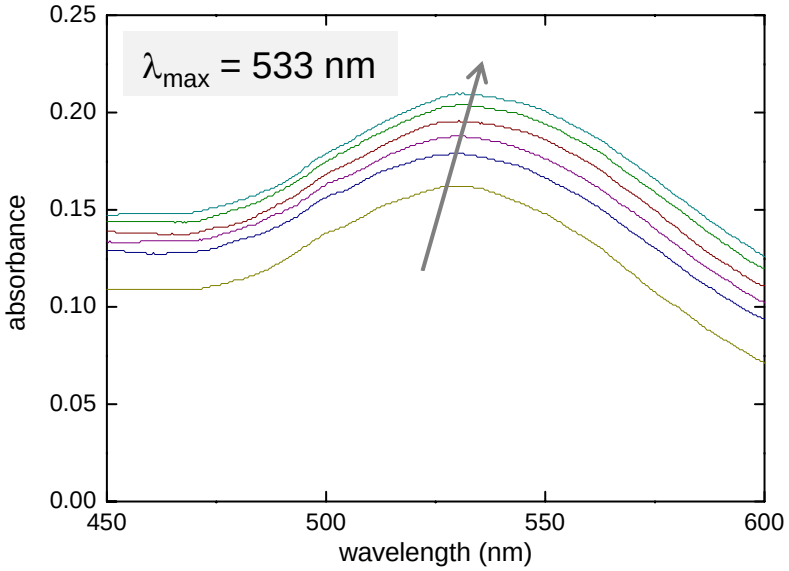
FTL

E = 165 μJ

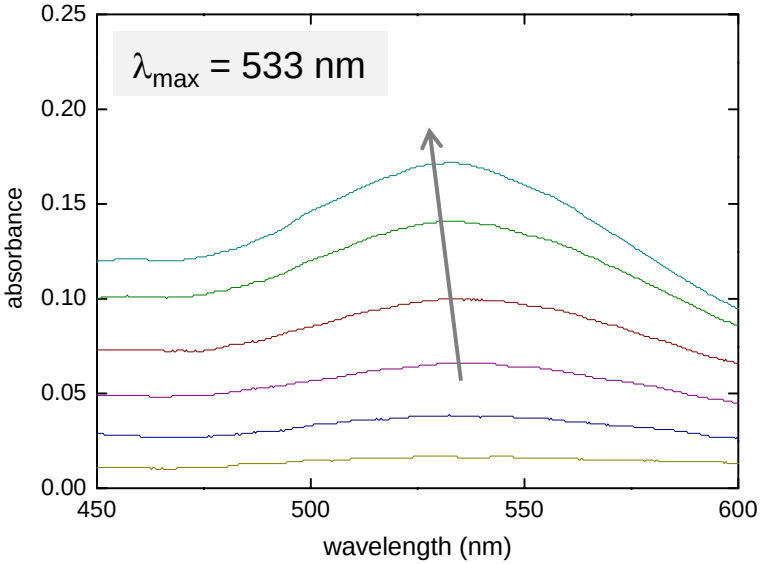


Results

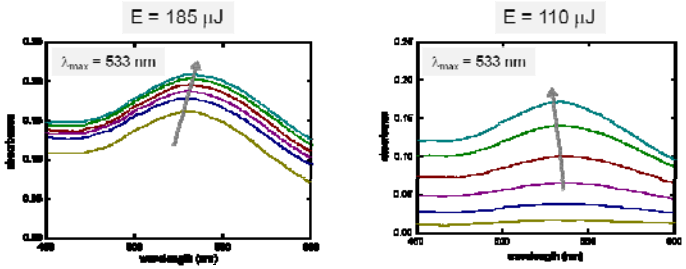
E = 185 μJ

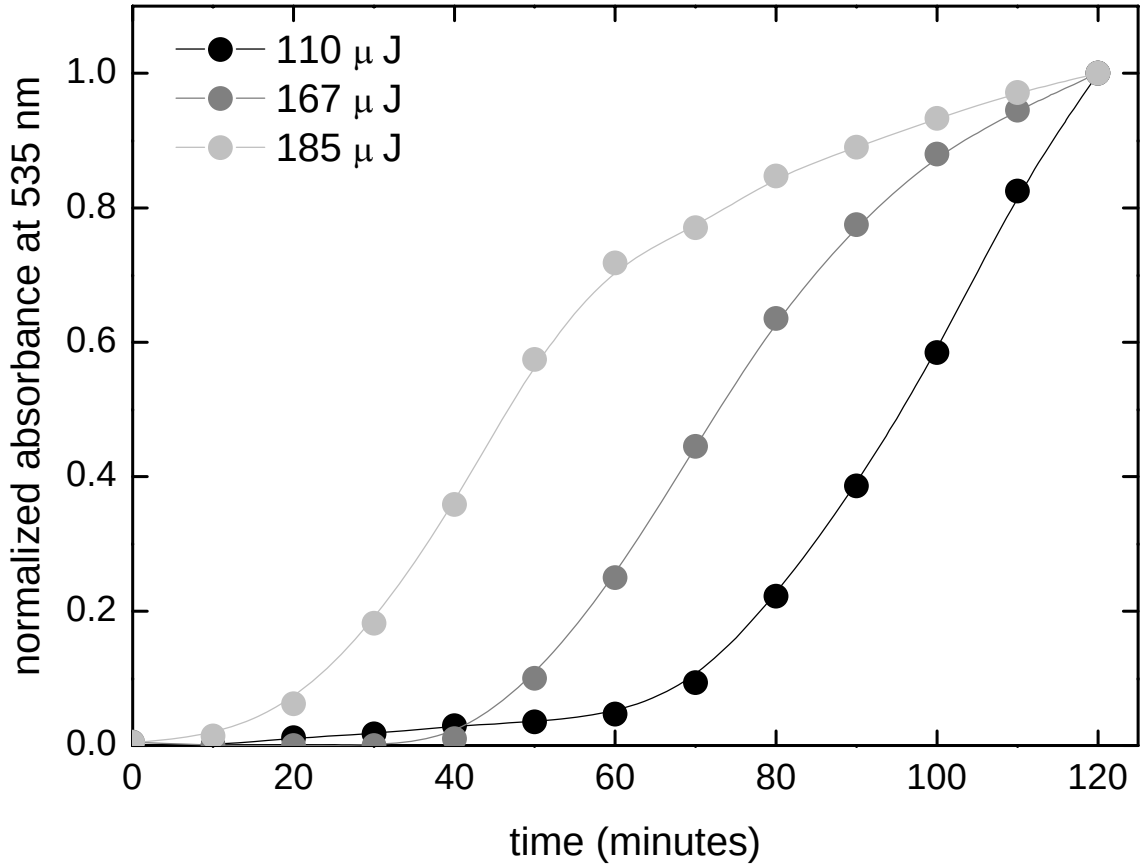


E = 110 μJ



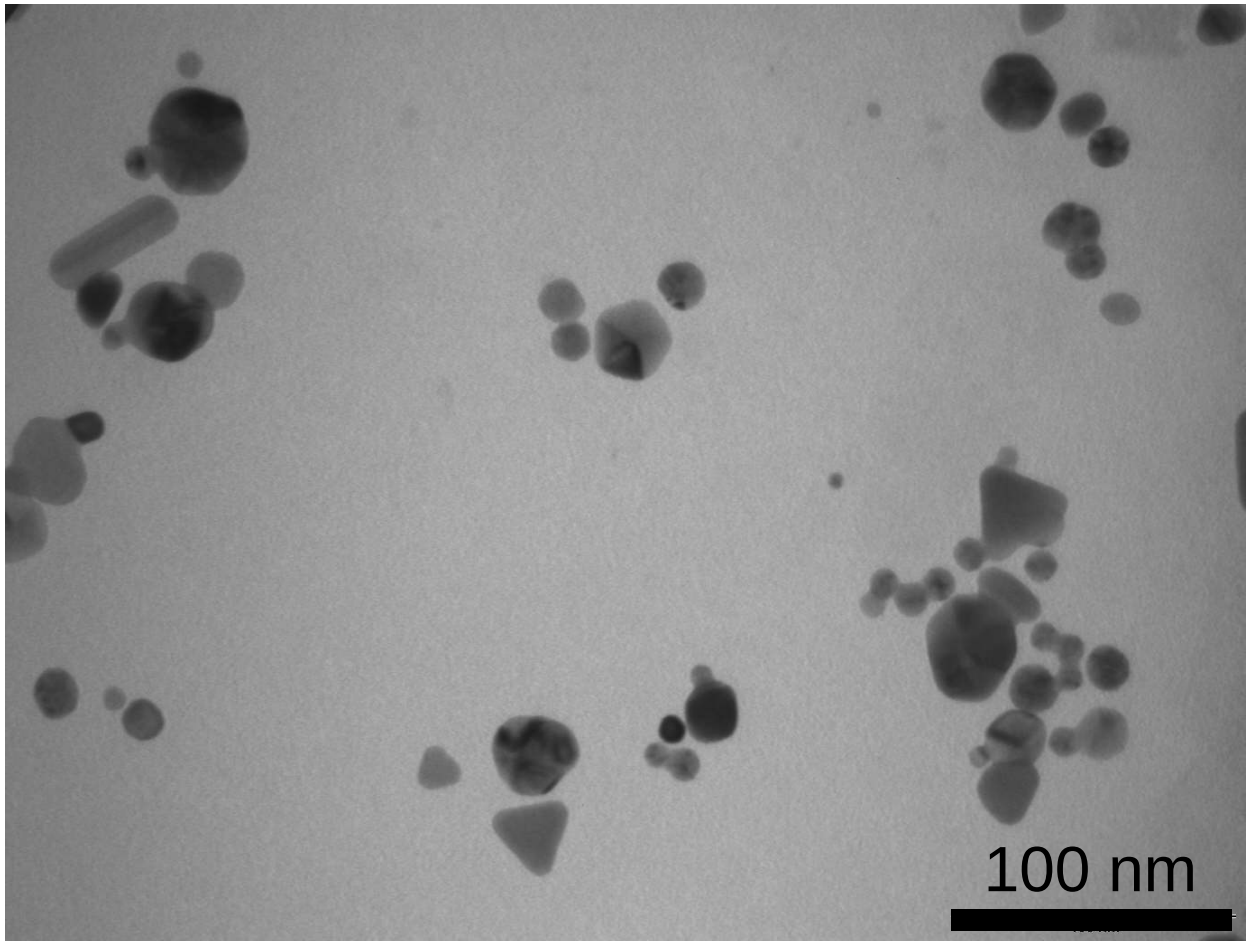
Results


E = 185 μJ
λ_{max} = 533 nm
E = 110 μJ
λ_{max} = 533 nm


110 μ J
167 μ J
185 μ J
normalized absorbance at 535 nm
0.0
0.2
0.4
0.6
0.8
1.0
0
20
40
60
80
100
120
time (minutes)

Results

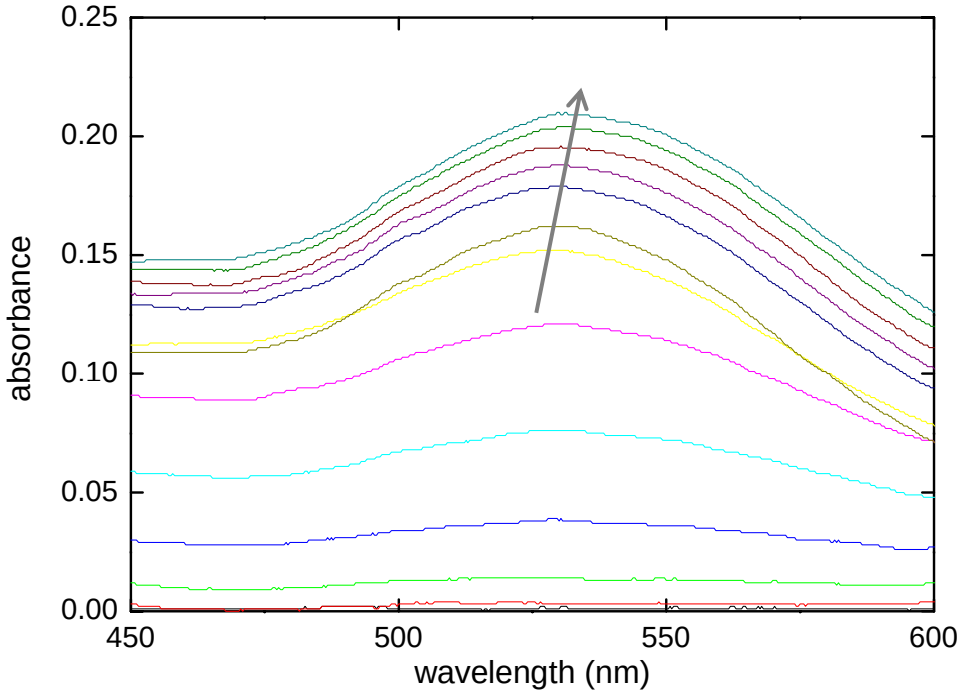
Gold nanoparticles – TEM images



Results

Fourier Transform Limited pulse

FTL pulse



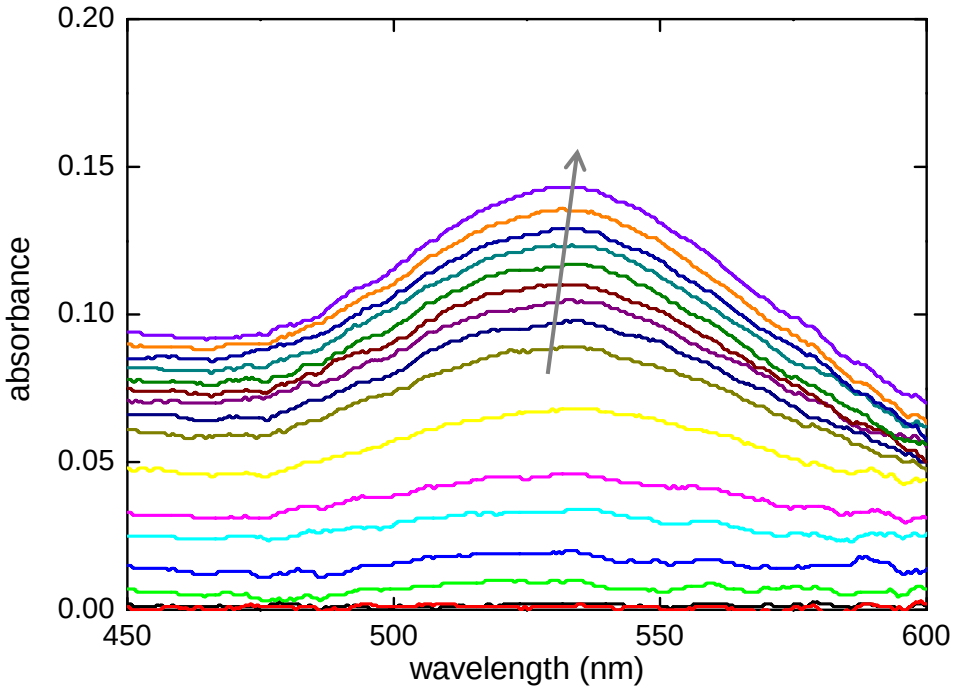
E = 180 μJ

λ_{max} = 533 nm

red shift

Results

Sine function



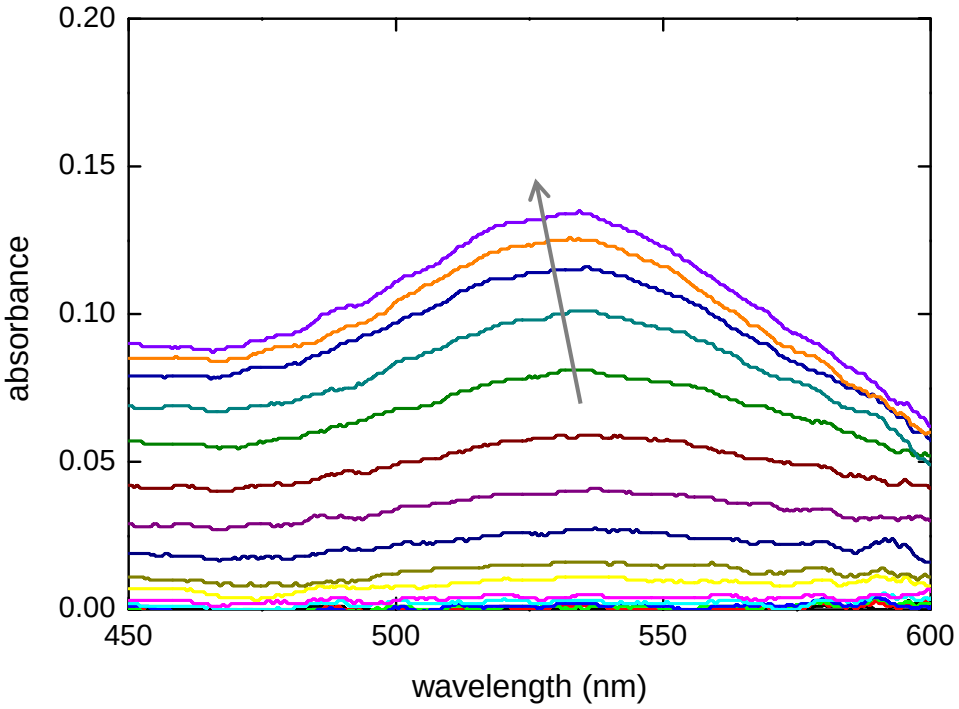
E = 180 μJ

λ_{max} = 532 nm

red shift

Results

Step function



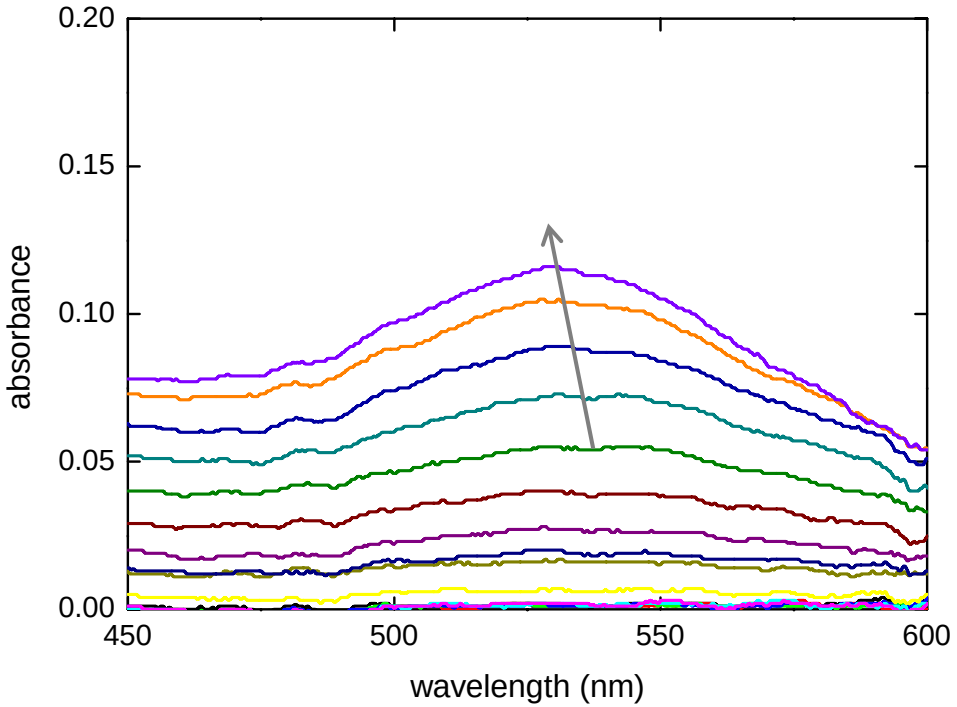
E = 180 μJ

λ_{max} = 533 nm

blue shift

Resuls

Cosine function

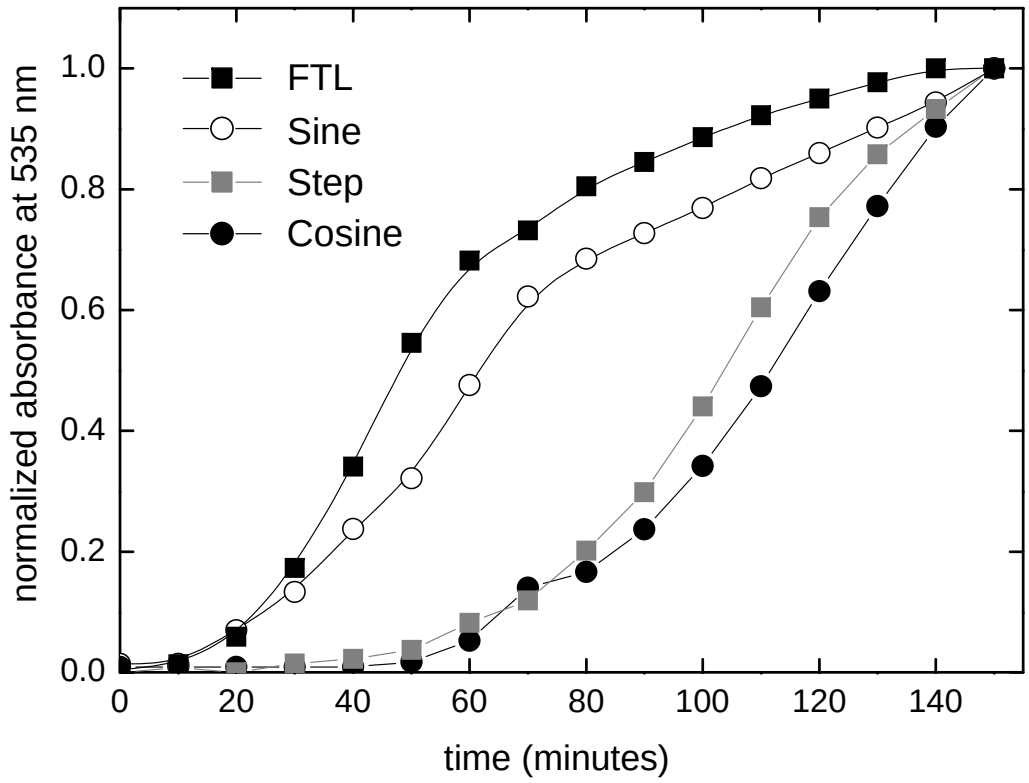


E = 180 μJ

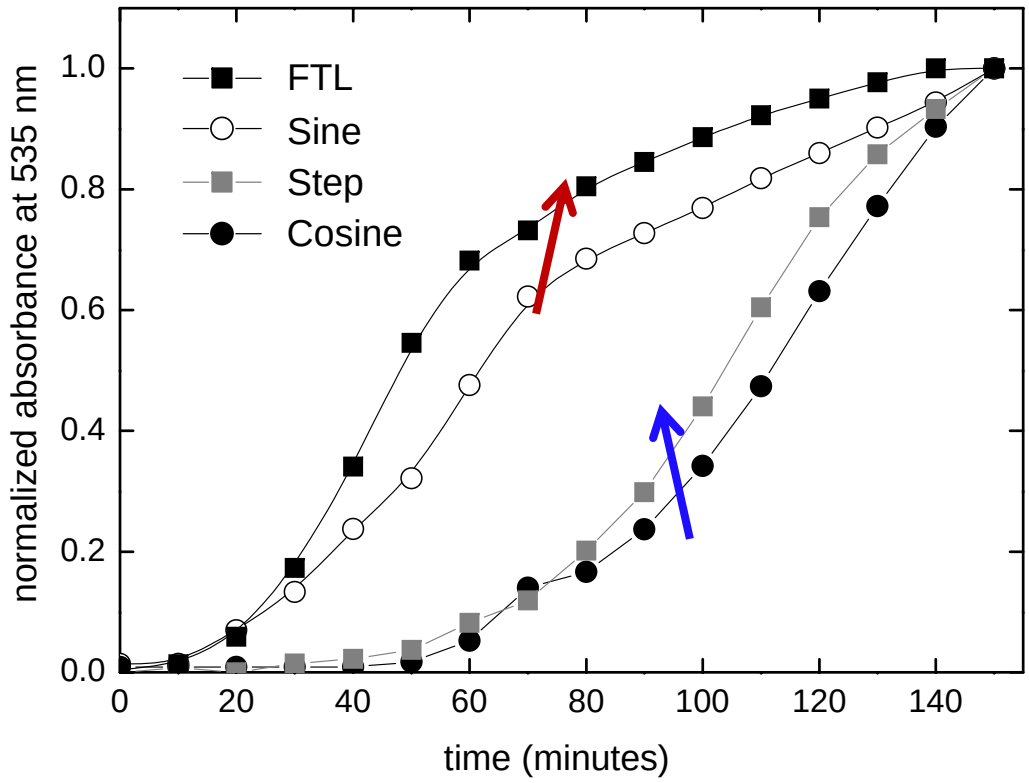
λ_{max} = 530 nm

blue shift

Results


FTL
Sine
Step
Cosine
normalized absorbance at 535 nm
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
120
140
time (minutes)

Results


FTL
Sine
Step
Cosine
normalized absorbance at 535 nm
1.0
0.8
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0.4
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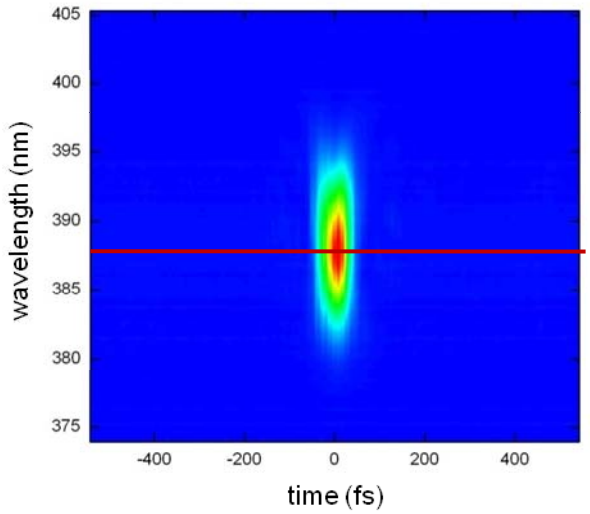
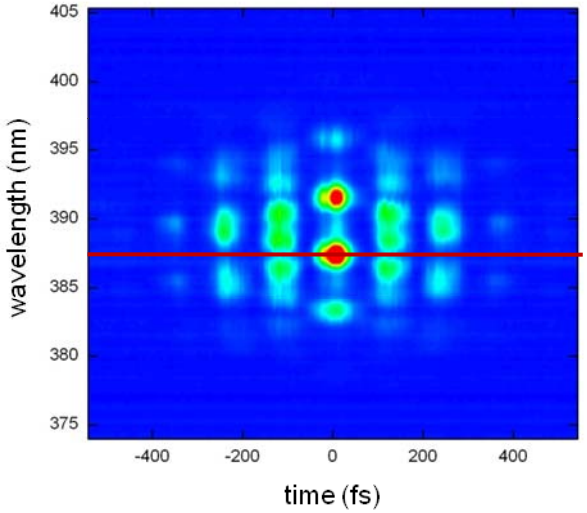
0
20
40
60
80
100
120
140
time (minutes)

Results

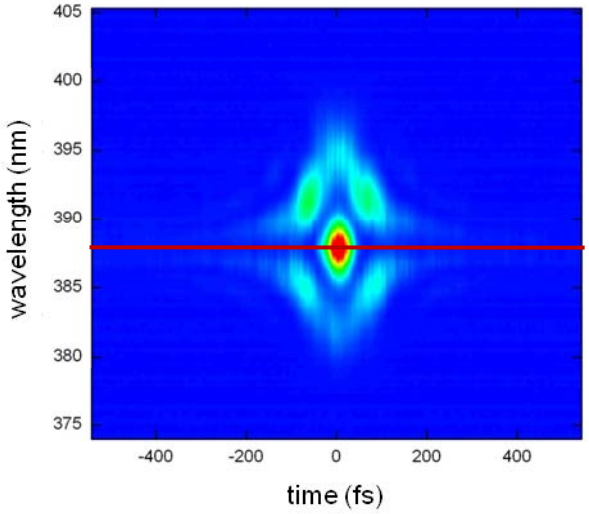
FTL



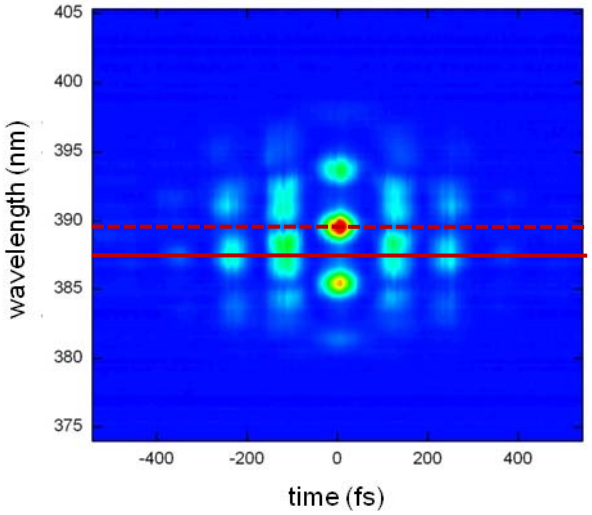
cosine



step



sine



Conclusions

- We demonstrate the coherent control of two-photon induced nanoparticles
- Two distinct dynamics have been observed depending on the phase mask, although the same final result is always achieved
- The results seems to be related to the spectral distribution of the second order field
- Further experiments need to be performed to understand the physical nature of the observed coherent control

Acknowledgments

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Acknowledgments

for a copy of this presentation

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