Generation of Ultrashort Pulses:
Basic concepts and nonlinear optics techniques

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OSA Ultrafast Optical Phenomena Technical Group Online Workshop

Why short pulses?

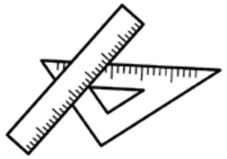
Blurry picture measured using an insufficiently short event.

When detectors are too slow...

… you need a light pulse which is faster than the process to be recorded

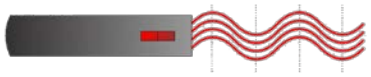
- Fastest incoherent light pulse: **$10 \cdot 10^{-9}$ s**

- **Lasers pulses**: duration down to **$10 \cdot 10^{-18}$ s**
- They are the **shortest artificial events** ever generated
- They are the **ruler** to measure ultrafast events in nature



Photograph taken by Harold Edgerton, MIT, 1964

A travel in time and space



Laser

Incoherent light

Electron motion: $\mathbf{10^{-18}}$ **s**

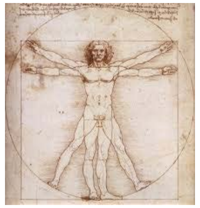
Molecular motion: $\mathbf{10^{-12}}$ **-** $\mathbf{10^{-15}}$ **s**

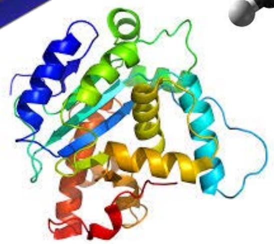
Macromolecules dynamics: $\mathbf{10^{-9}}$ **s**

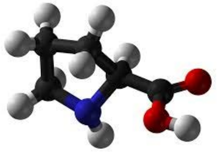
Heart beat: **1 s**

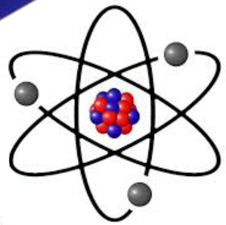
Average life of man: $\mathbf{10^{9}}$ **s**

Age of universe:
$\mathbf{4.3 \times 10^{17}}$ **s**





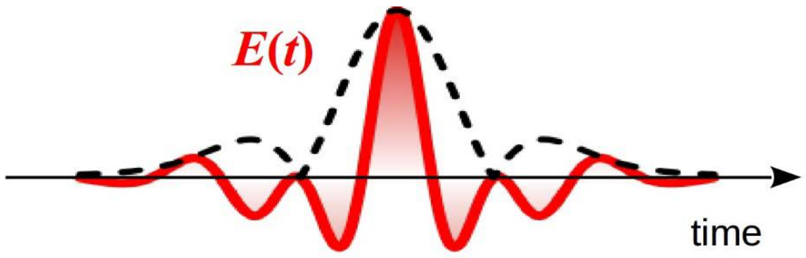


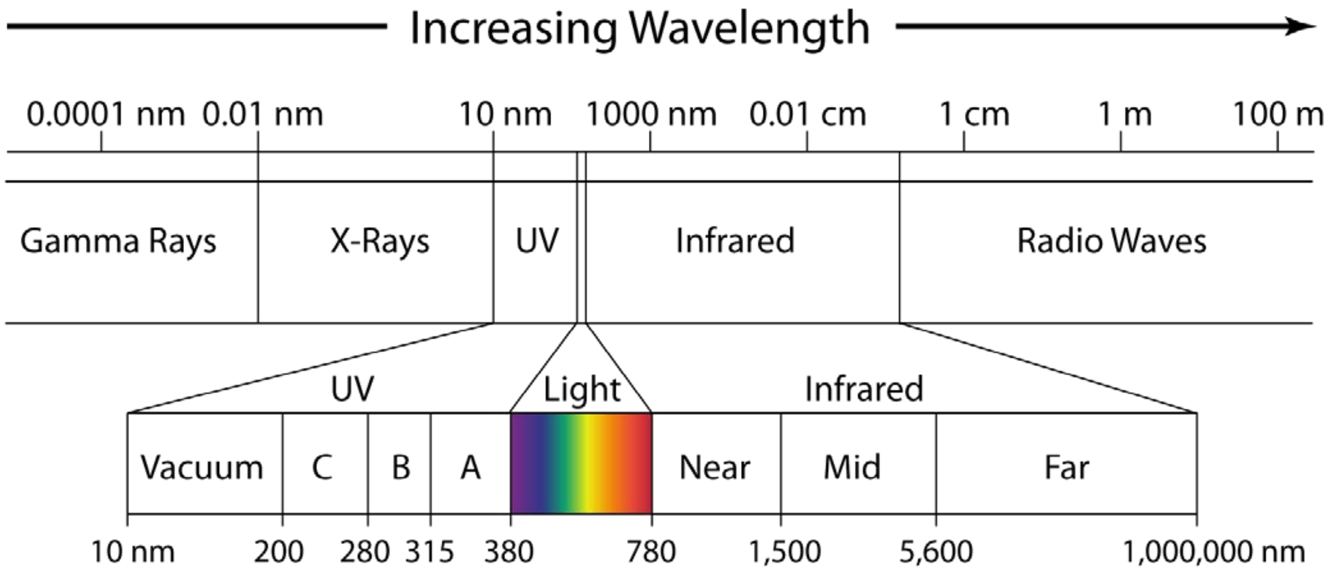


Properties of a light pulse

Pulse $E(t)$:

Product between **envelope** and **carrier**





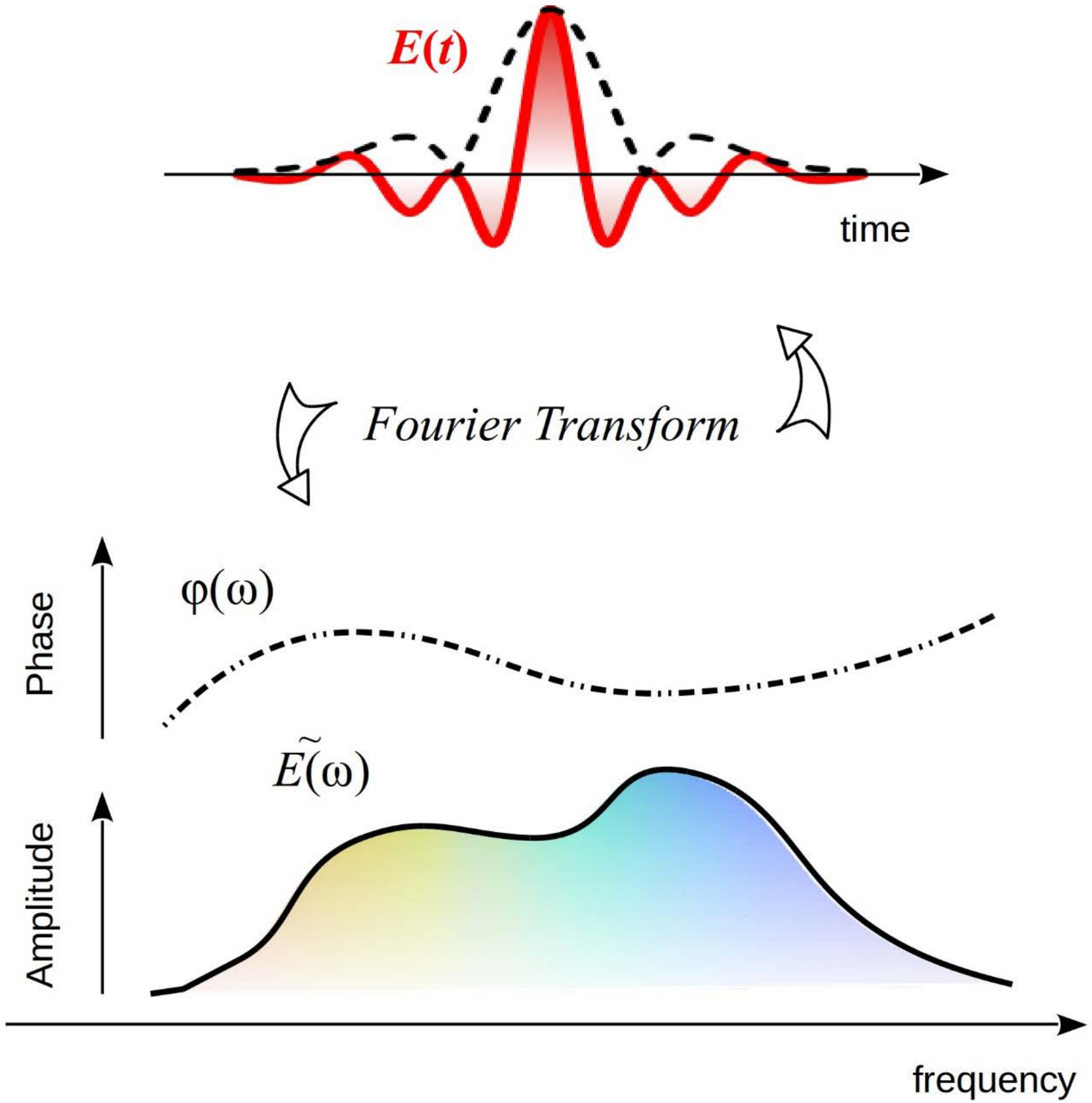
$33\cdot10^{-18}$ 10^{-15} $5\cdot10^{-15}$ $100\cdot10^{-15}$ $3\cdot10^{-12}$

Increasing Optical Cycle (seconds) →

Representation of optical pulses

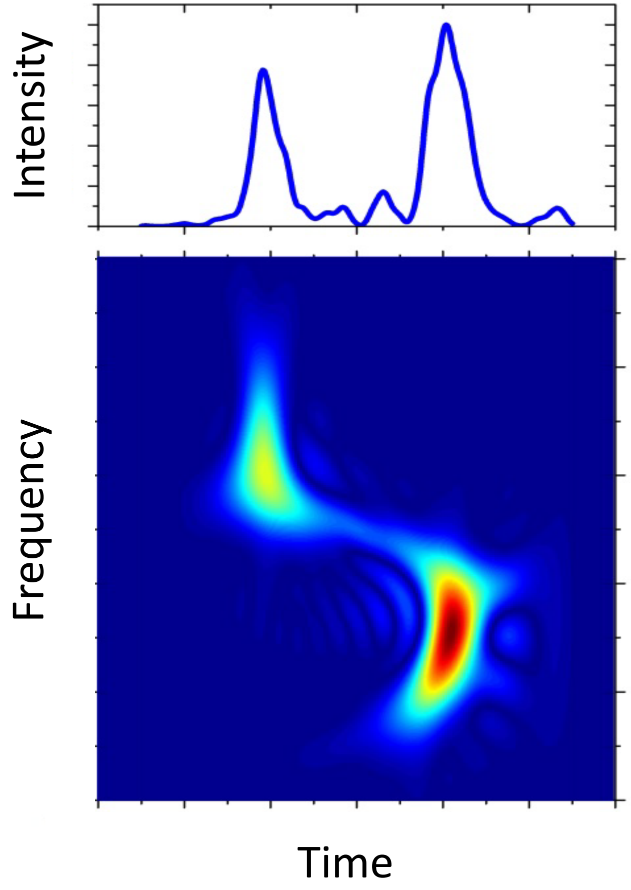
time

frequency



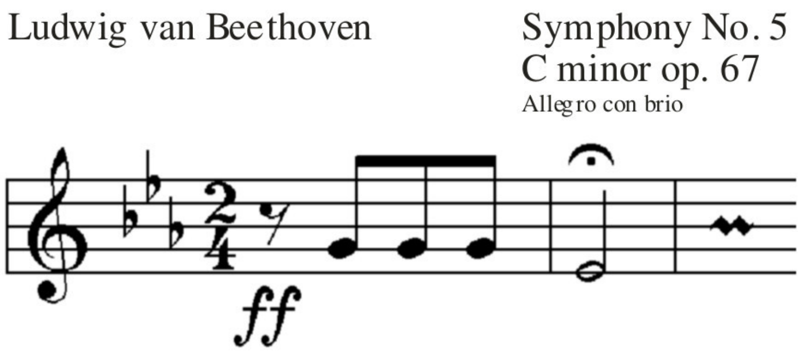
Chronocyclic Wigner function

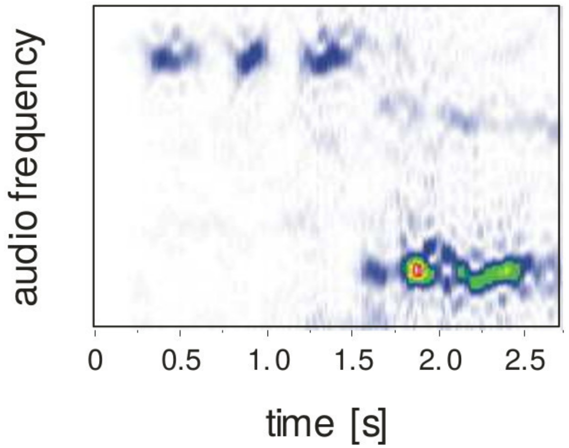
Time - frequency



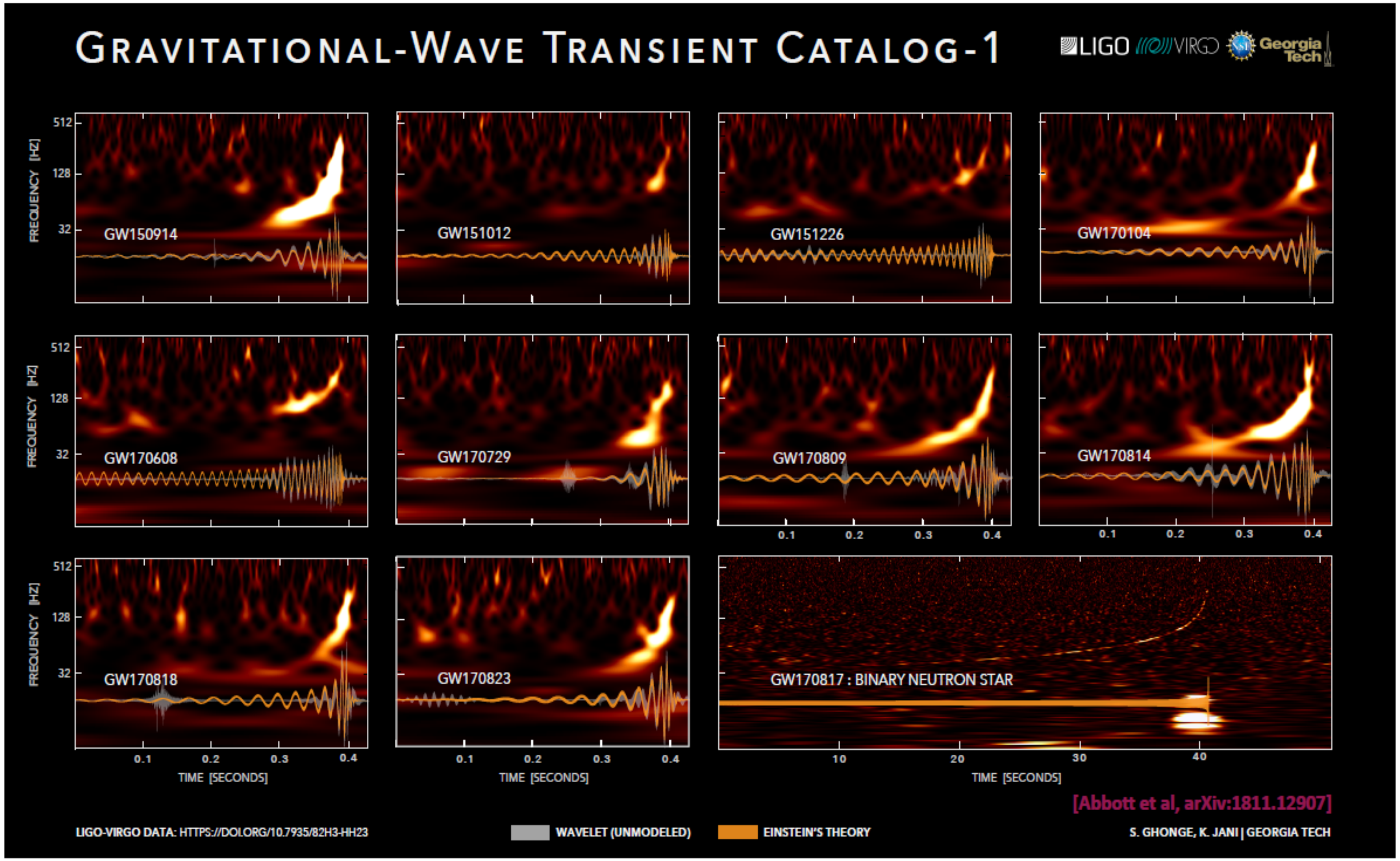
J. Paye, IEEE J. Quantum Electron. 28, 2262–2273 (1992)

Examples of chronocyclic functions





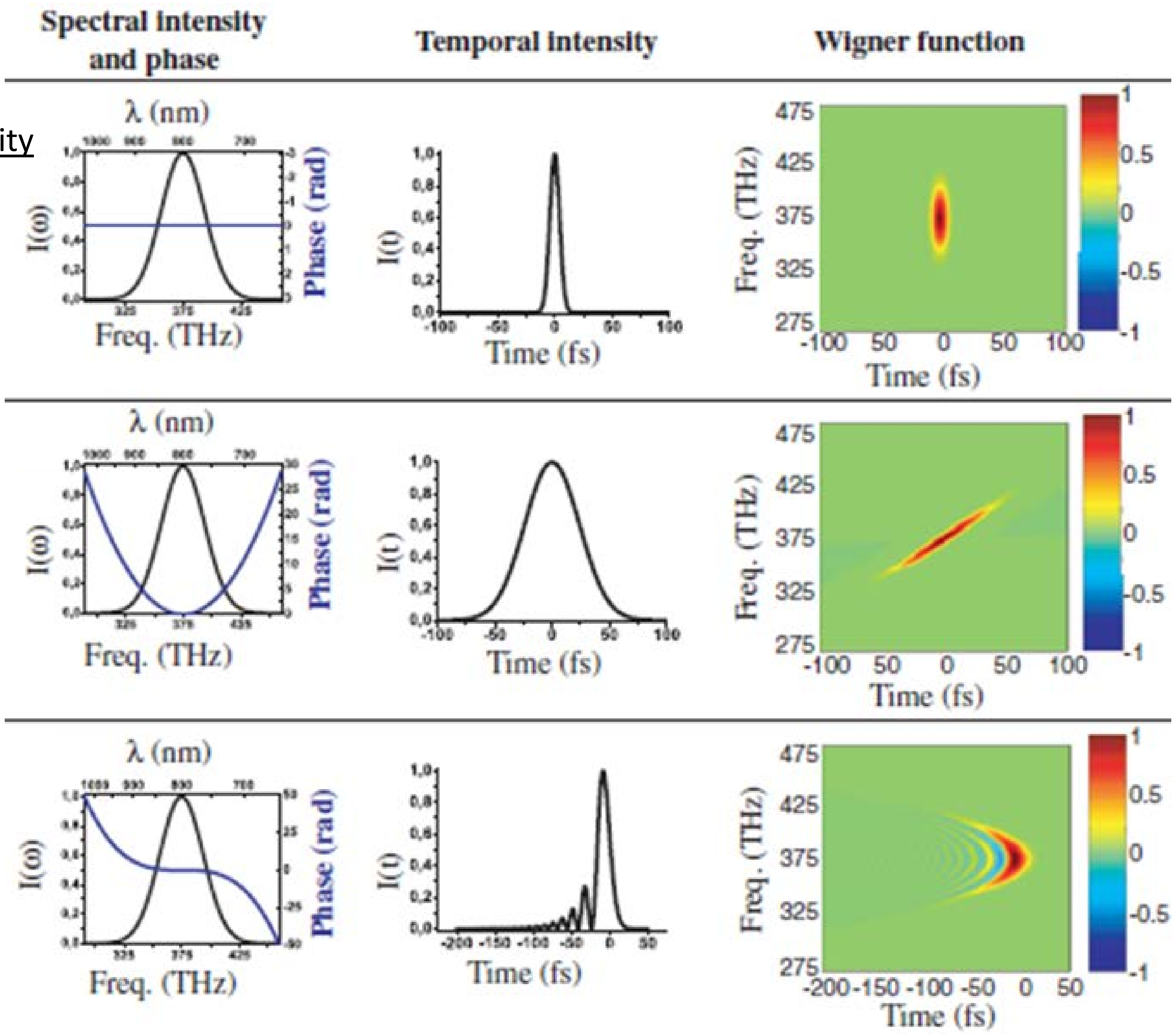
The musical score lives
in the **time-frequency** domain



https://www.gw-openscience.org/GWTC-1/
DOI: 10.7935/82H3-HH23 - https://arxiv.org/abs/1811.12907

Examples of pulses

Intensity
Phase



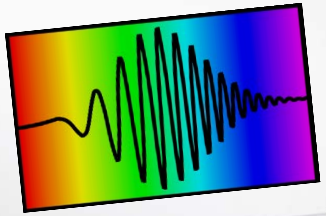
Transform-limited

Group-delay dispersion (GDD)

Third-order dispersion (TOD)

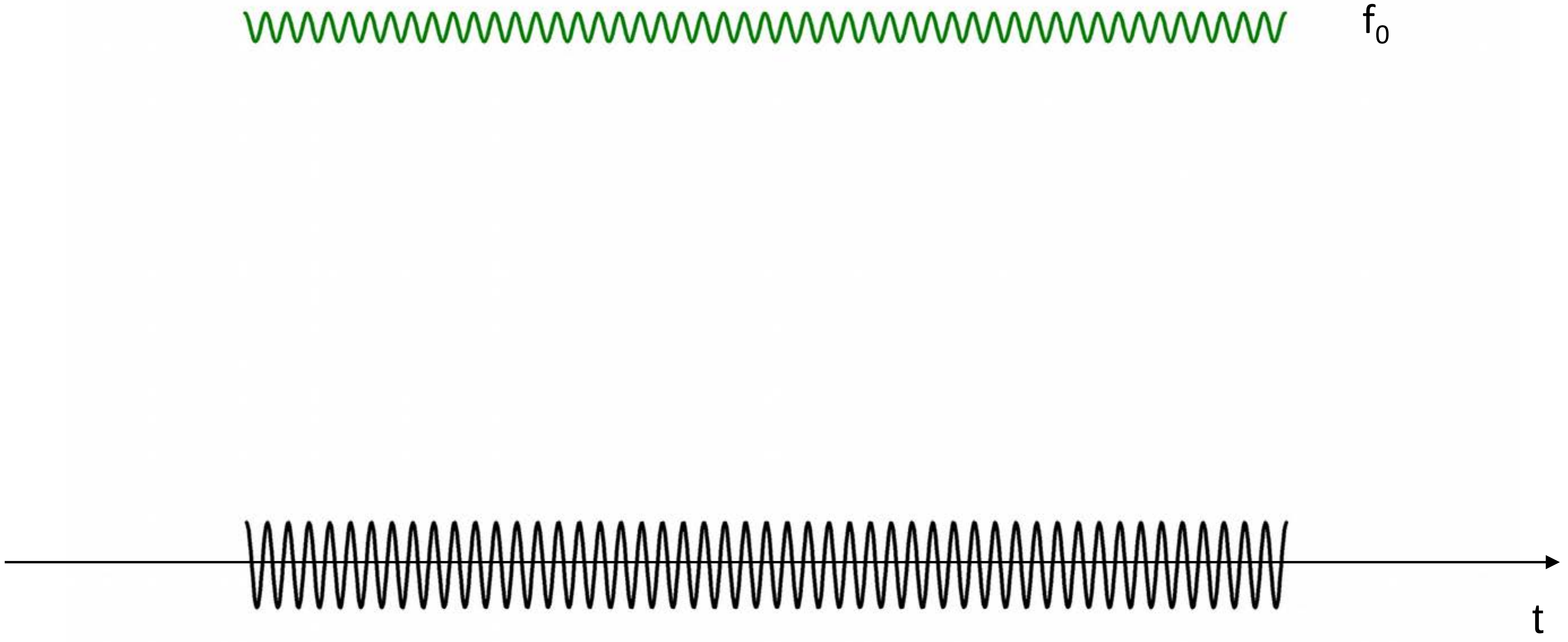
$$GD = {\partial\varphi}/{\partial\omega}$$

Group delay: determines the pulse's frequency (i.e., color) *vs.* time



A. Monmayrant, S. Weber, B. Chatel, J. Phys. B: At. Mol. Opt. Phys. 43 (2010) 103001
doi: 10.1088/0953-4075/43/10/103001

Pulse: Overlap of phase-coherent waves



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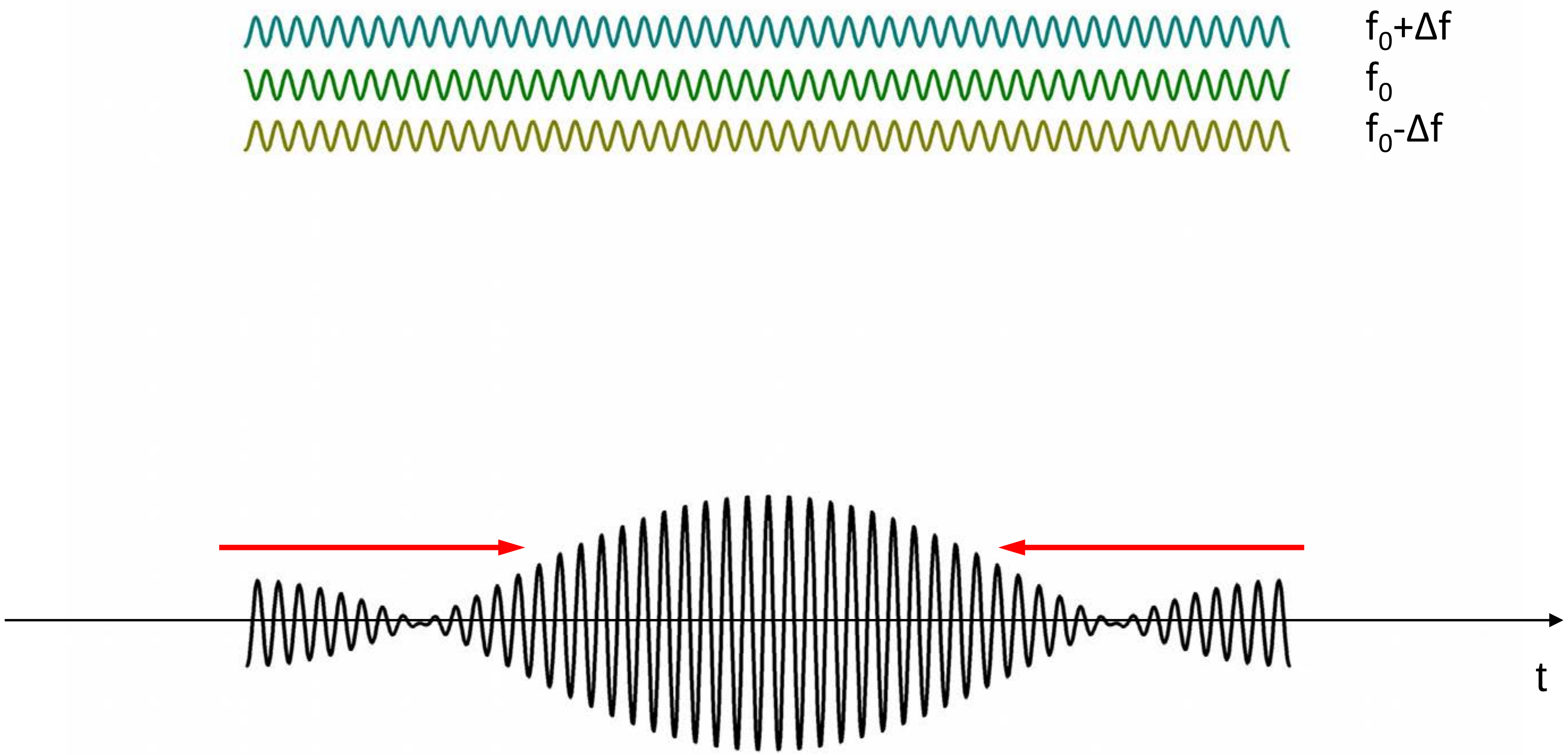

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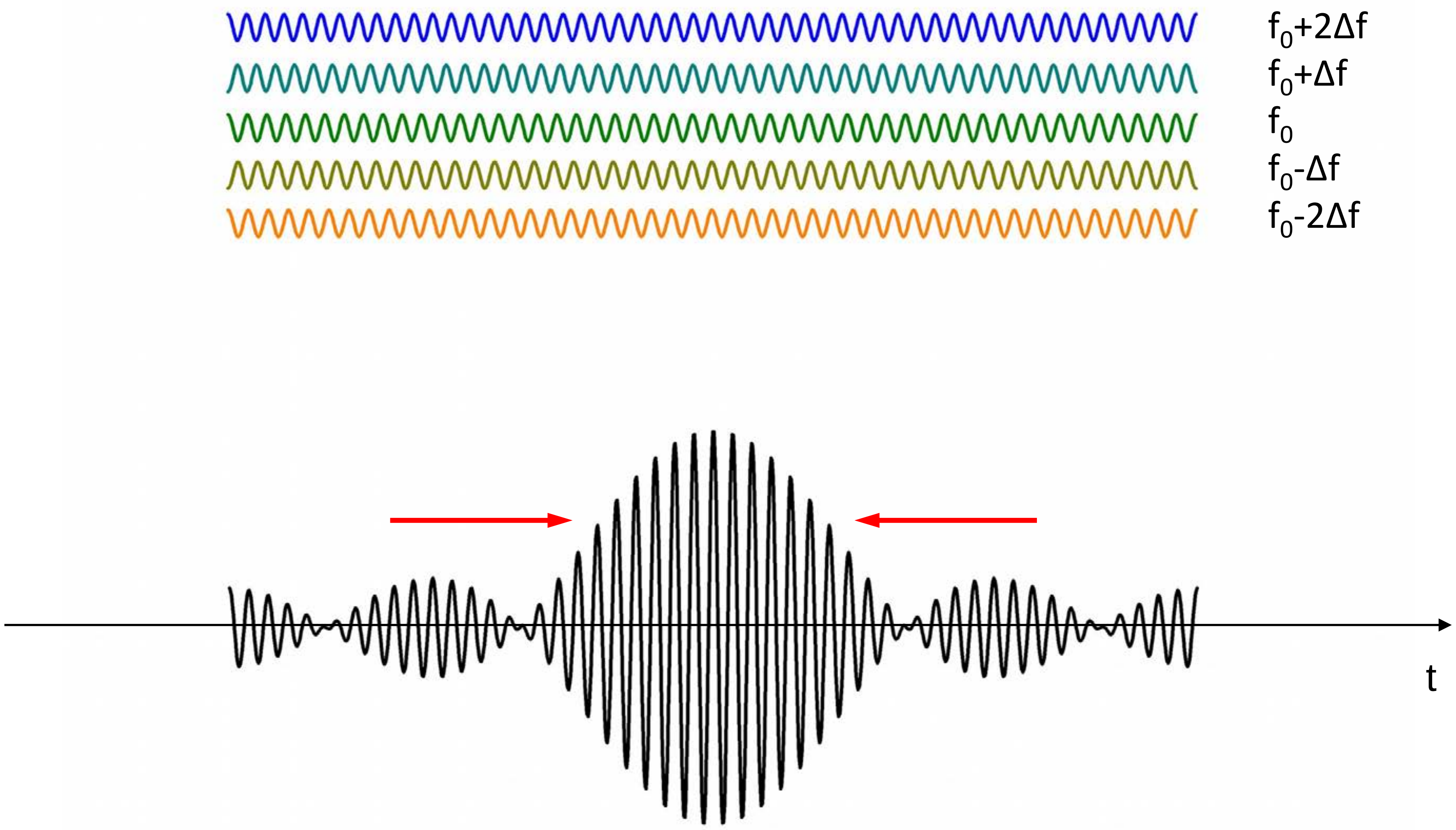

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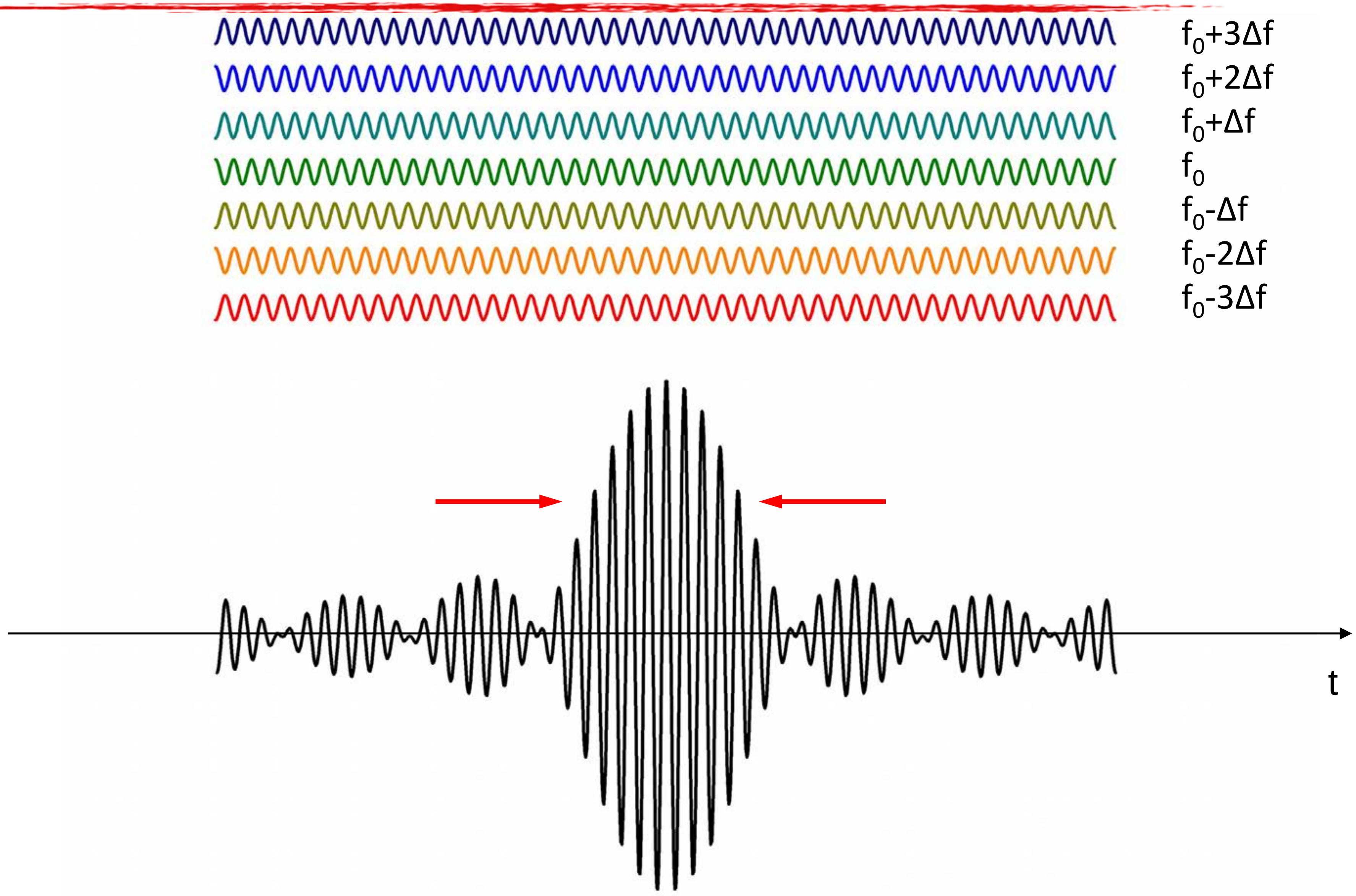

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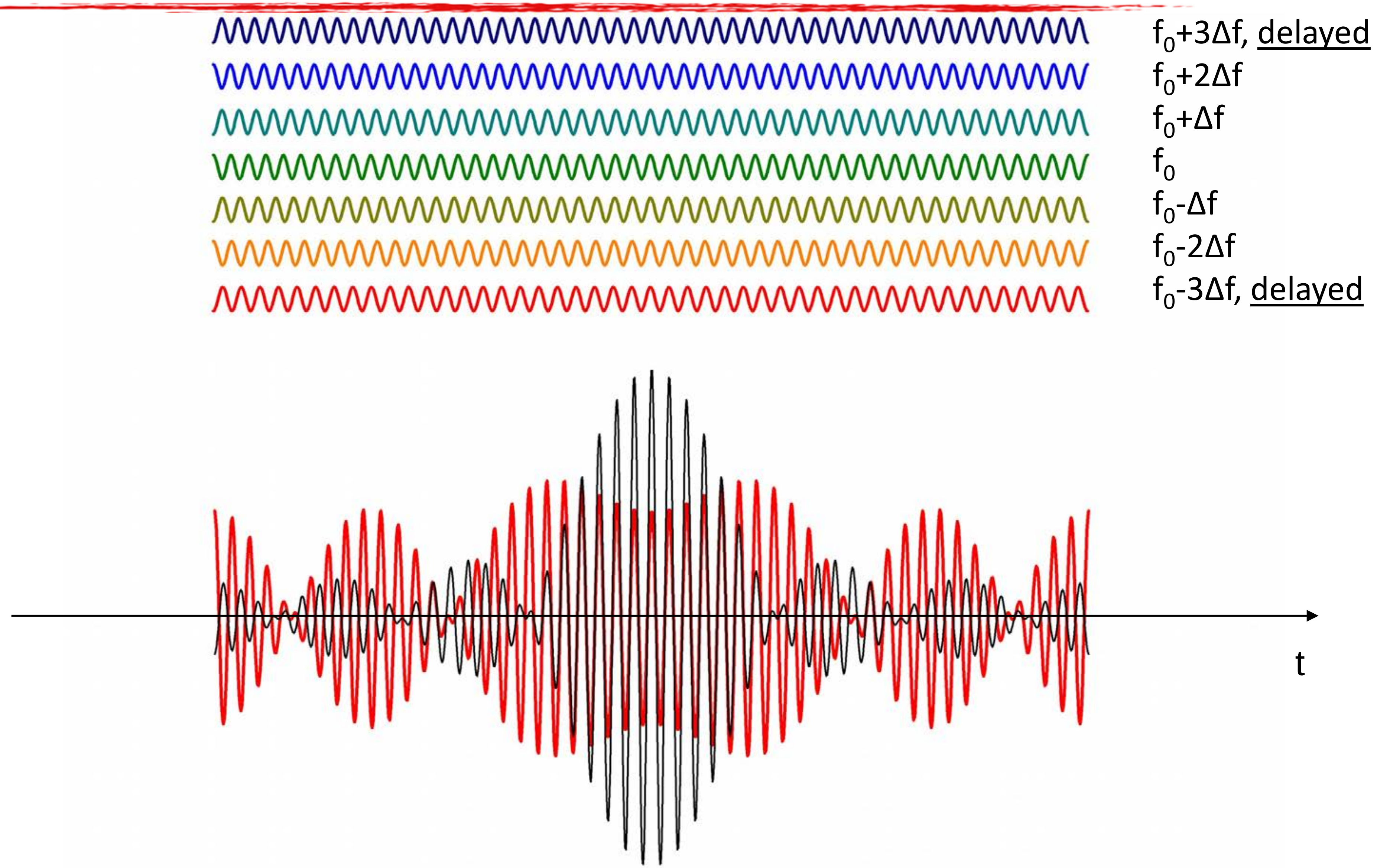

Outline

- Turn-key sources of ultrashort pulses
- Nonlinear processes: wave equations
  - ✓ General equation
  - ✓ Second order processes
  - ✓ Coupled nonlinear equations
  - ✓ Meaning of phase matching (I)
- Corpuscular view of second order processes
  - ✓ Manley-Rowe equations
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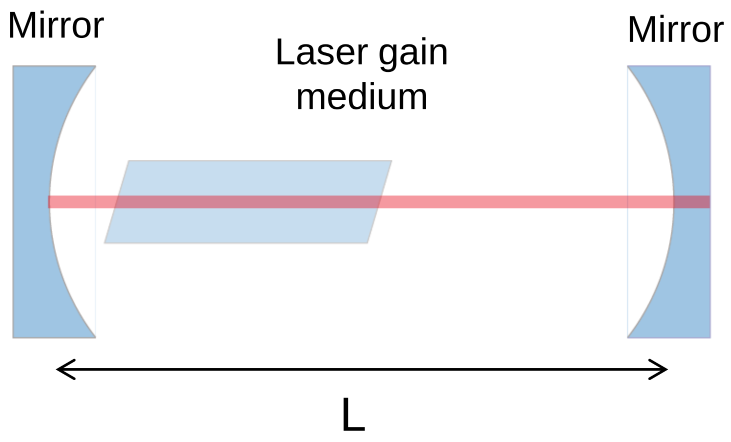
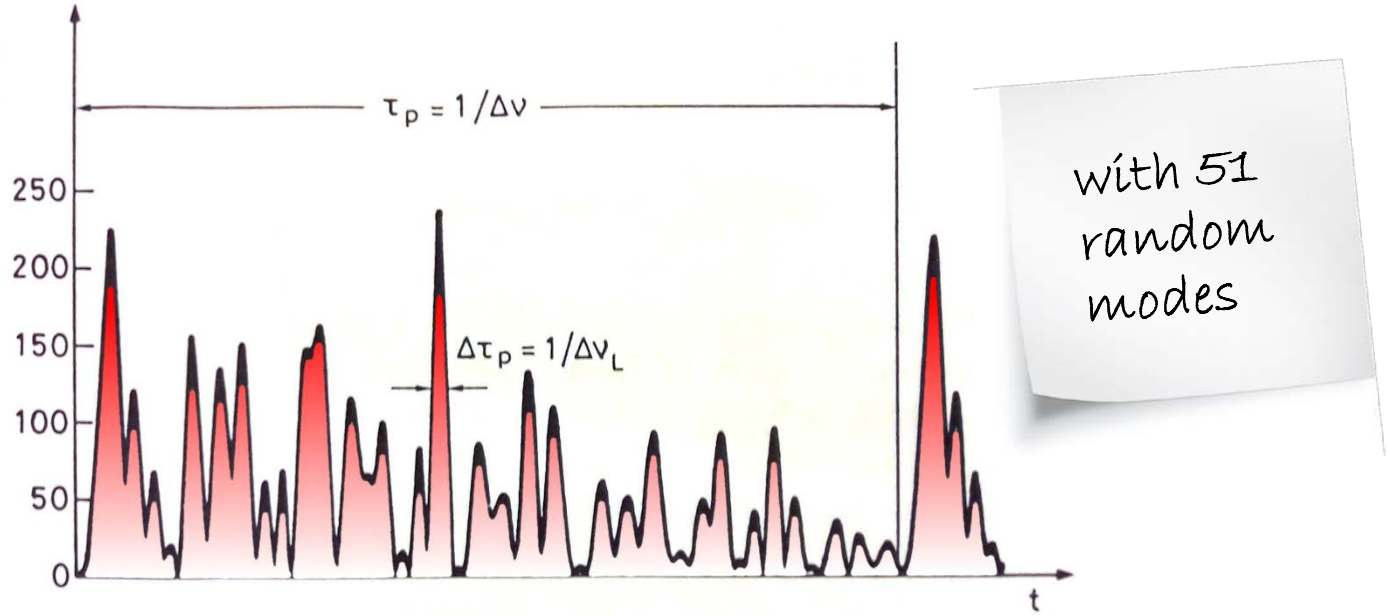
- Fulfilling phase matching
- Second order processes with pulses
  - ✓ Temporal overlap
  - ✓ Broadband phase matching

Laser mode locking

- A laser is an optical oscillator which consists of an optical amplifying medium enclosed between two high reflectance mirrors
- A laser allows longitudinal modes which are spaced in frequency by the resonance condition: $\Delta\nu = c/2L$.

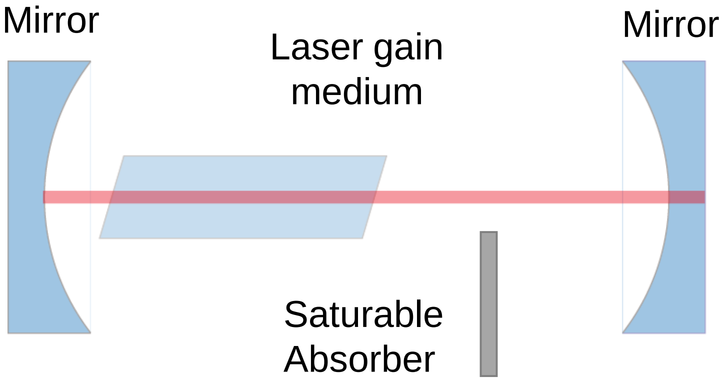


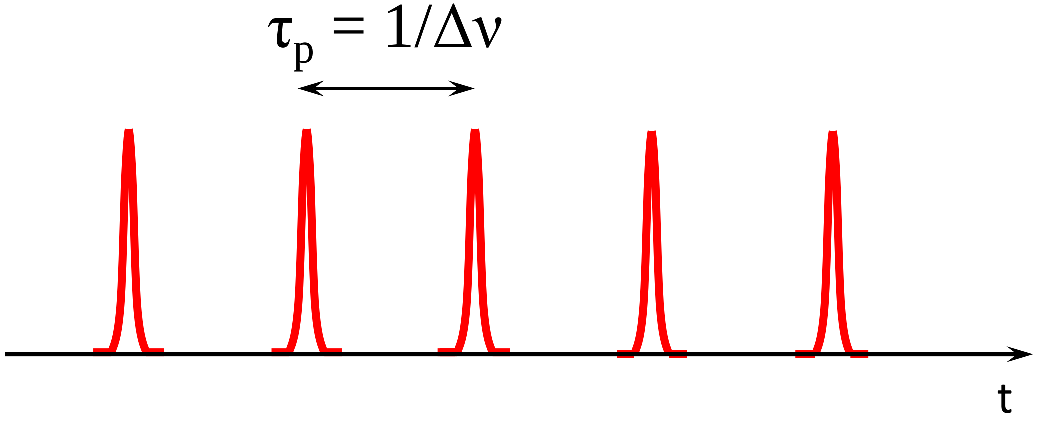


- In a mode-locked laser all the modes oscillate with a constant phase difference. How is this locking obtained?

Laser mode locking: time domain

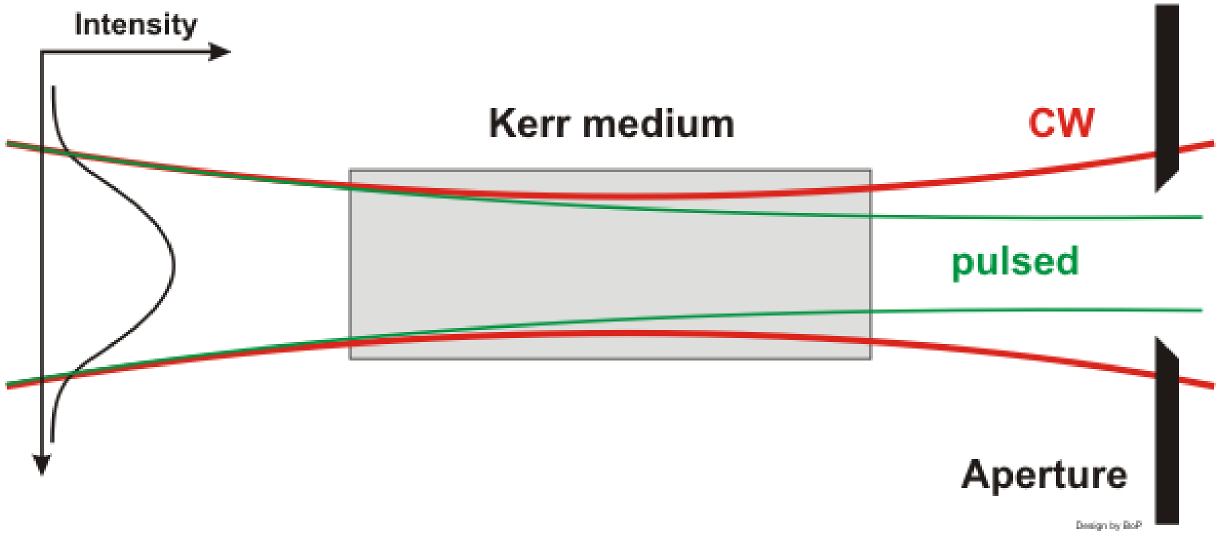
- A mode-locked laser incorporates an ultrafast optical switch, which drives the ultrashort pulse generation





- The <u>*saturable absorber*</u> transmits the intense laser pulse and absorbs the less intense CW radiation

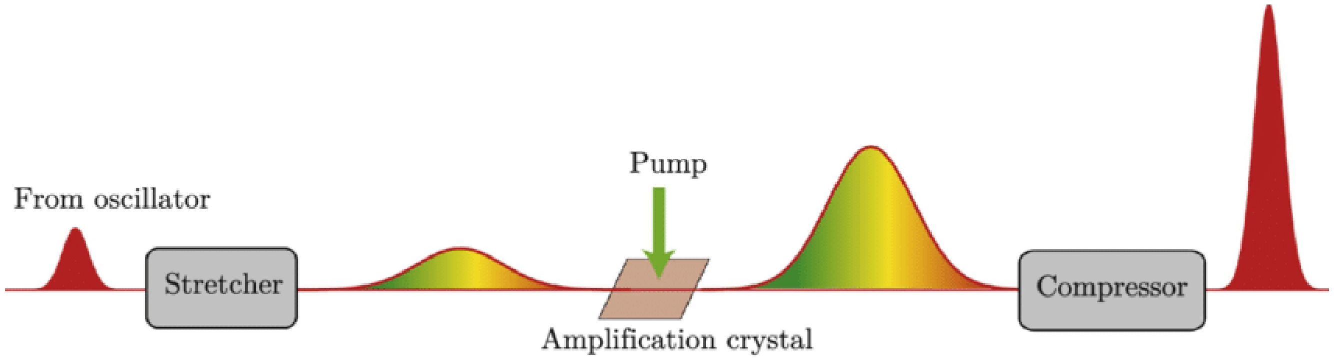
Kerr-lens mode-locking



A Kerr medium has a refractive index that depends on intensity, so it acts as a lens for the high intensity (pulsed) beam

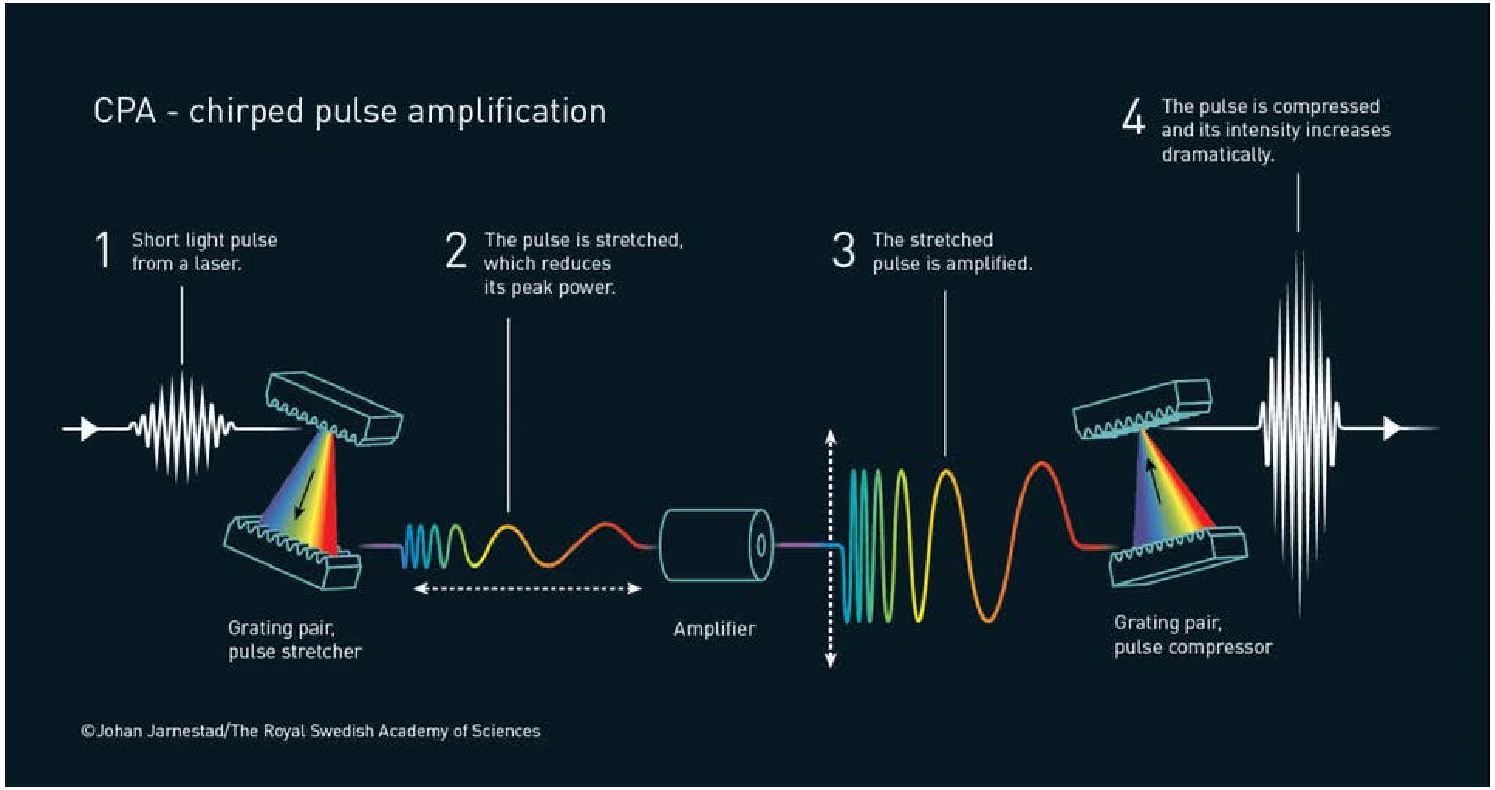
Together with an aperture it induces a transmission that increases with intensity $\rightarrow$ saturable absorber

Chirped pulse amplification (CPA)



- ✓ Boosting the oscillator pulse energy by many orders of magnitude
- ✓ no damage of the amplification crystal

Donna Strickland and
Gerard Mourou
Physics Nobel prize 2018



CPA laser sources

- Ti:sapphire pumped by green laser: wavelength **800 nm**
  - Pulse energy 1-10 mJ
  - Repetition rate 1-10 kHz
  - Pulsewidth: 30-100 fs

- Diode-pumped Yb laser: wavelength **1040 nm**
  - Pulse energy 0.01-10 mJ
  - Repetition rate 1kHz-2 MHz
  - Pulsewidth: 150-300 fs

For both these sources the wavelength is fixed
We need nonlinear optics to achieve frequency tunability

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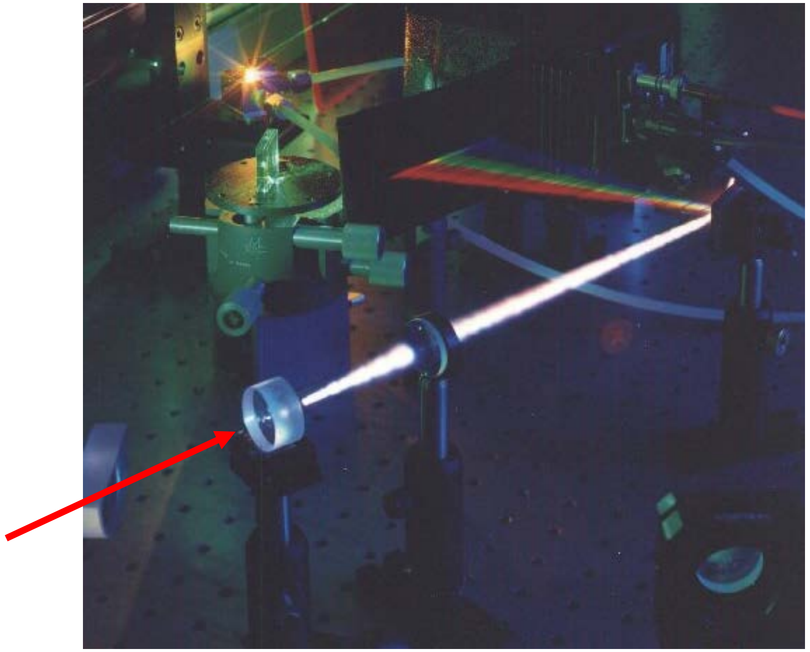
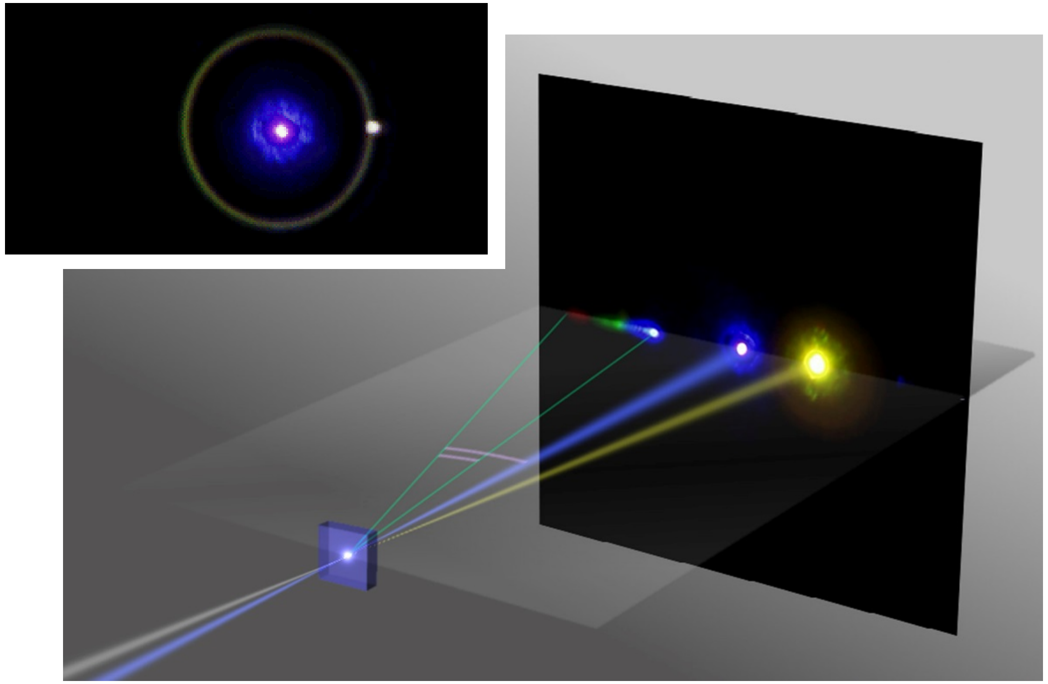
Tuning by nonlinear optics

- Spectral broadening
  - third order effect -



- Parametric amplification
  - Second order effect -

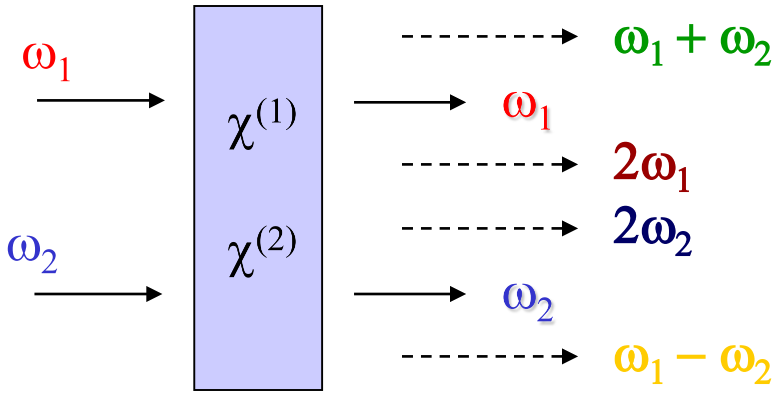


Nonlinear interactions

High-intensity fields

$$P = \varepsilon_0 \chi^{(1)} E + \varepsilon_0 \chi^{(2)} E^2 + \varepsilon_0 \chi^{(3)} E^3 + \dots$$

Weak fields



C. Manzoni and G. Cerullo, "Design criteria for ultrafast optical parametric amplifiers", J. Opt. 18, 103501 (2016)

Nonlinear processes: wave equations

- Starting from Maxwell's equation for wave propagation:

$$\frac{\partial^2 E}{\partial z^2} - \frac{1}{c_0^2}\frac{\partial^2 E}{\partial t^2} = \mu_0 \frac{\partial^2 P}{\partial t^2}$$

- Polarization:

High-intensity fields

$$P(z,t) = P_{\mathrm{L}}(z,t) + P_{\mathrm{NL}}(z,t)$$

Weak fields

$$\frac{\partial^2 E}{\partial z^2} - \frac{1}{c_0^2}\frac{\partial^2 E}{\partial t^2} = \mu_0 \frac{\partial^2 P_L}{\partial t^2} + \mu_0 \frac{\partial^2 P_{NL}}{\partial t^2}$$

Nonlinear processes: wave equations

$$\frac{\partial^2 E}{\partial z^2} - \frac{1}{c_0^2}\frac{\partial^2 E}{\partial t^2} = \mu_0 \frac{\partial^2 P_L}{\partial t^2} + \mu_0 \frac{\partial^2 P_{NL}}{\partial t^2}$$

$$D(z,t) = \varepsilon_0 E(z,t) + P_{\mathrm{L}}(z,t)$$

General wave equation with nonlinear processes:

$$\frac{\partial^2 E(z,t)}{\partial z^2} - \mu_0 \frac{\partial^2 D(z,t)}{\partial t^2} = \mu_0 \frac{\partial^2 P_{\mathrm{NL}}(z,t)}{\partial t^2}$$

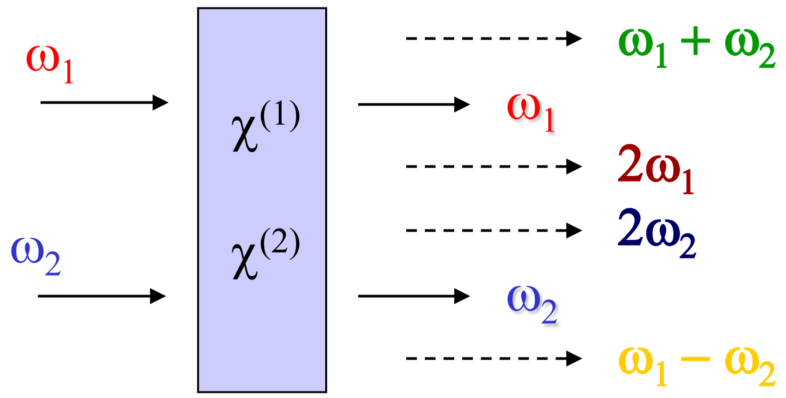
- In the following: **second order nonlinear processes:**

$$P_{\mathrm{NL}}(z,t) = \varepsilon_0 \chi^{(2)} E^2(z,t) = 2\varepsilon_0 d_{\mathrm{eff}} E^2(z,t)$$

Second order processes

- What is the meaning of $E(t)^2$?
  - ✓ Let's start from 2 oscillating fields:

$$E(t) = A_1 \exp(-i\omega_1 t) + A_2 \exp(-i\omega_2 t) + cc$$



optical rectification
- does not oscillate -

Second harmonic generation (SHG)

$$E^2(t) = \left(A_1A_1^* + A_2A_2^*\right) + A_1^2 \exp(-2i\omega_1 t) + A_2^2 \exp(-2i\omega_2 t) +$$

$$+ 2A_1A_2 \exp[-i(\omega_1 + \omega_2)t] + 2A_1A_2^* \exp[-i(\omega_1 - \omega_2)t] + cc$$

Sum frequency generation (SFG)

Difference frequency generation (DFG)

Source of second order processes

- 3 interacting waves:

$$E(z,t) = \frac{1}{2}\{A_1(z)e^{j(\omega_1 t - k_1 z)} + A_2(z)e^{j(\omega_2 t - k_2 z)} + A_3(z)e^{j(\omega_3 t - k_3 z)}\} + \text{c.c.}$$

with: $\omega_1 + \omega_2 = \omega_3$

Monochromatic waves

- Forcing term for Maxwell's equation:

$$\frac{\partial^2 P_{NL}(z,t)}{\partial t^2} = -\varepsilon_0 d_{\text{eff}}\omega_1^2 A_2^*(z)\cdot A_3(z)\cdot e^{j[\omega_1 t-(k_3-k_2)z]} - \varepsilon_0 d_{\text{eff}}\omega_2^2 A_1^*(z)\cdot A_3(z)\cdot e^{j[\omega_2 t-(k_3-k_1)z]} - \varepsilon_0 d_{\text{eff}}\omega_3^2 A_1(z)\cdot A_2(z)\cdot e^{j[\omega_3 t-(k_1+k_2)z]} + \text{c.c}$$

$$\frac{\partial^2 E(z,t)}{\partial z^2} - \mu_0\frac{\partial^2 D(z,t)}{\partial t^2} = \mu_0\frac{\partial^2 P_{NL}(z,t)}{\partial t^2}$$

Coupled nonlinear equations

✓ Slowly varying envelope approximation : $\left|\frac{\partial^2 A}{\partial z^2}\right| \ll 2k \left|\frac{\partial A}{\partial z}\right|$

$$\begin{cases} \frac{\partial A_1}{\partial z} = -j\sigma_1 A_2^* A_3 \cdot \mathrm{e}^{-j\Delta kz}, \\ \frac{\partial A_2}{\partial z} = -j\sigma_2 A_1^* A_3 \cdot \mathrm{e}^{-j\Delta kz}, \\ \frac{\partial A_3}{\partial z} = -j\sigma_3 A_1 A_2 \cdot \mathrm{e}^{j\Delta kz}, \end{cases}$$

$$\omega_1 + \omega_2 = \omega_3$$

Where:

$$\sigma_i = d_{\mathrm{eff}}\,\omega_i / c_0 n_i$$

$$\Delta k = k_3 - k_2 - k_1$$

Phase mismatch

Example 1: Sum frequency generation

- Boundary conditions:

  ✓ Negligible depletion of $A_1(z)$: $\frac{\partial A_1(z)}{\partial z} = 0$

  ✓ No A_3 field: $A_3(0)=0$

$$\omega_1 + \omega_2 = \omega_3$$

$$I_3(z) = \Gamma^2 \frac{\omega_3}{\omega_2} I_1 \cdot I_{20} \cdot \left| \frac{\sin(gz)}{g} \right|^2$$

$$\Gamma^2 = \frac{2d_{eff}^2 \omega_2 \omega_3}{c_0^3 \varepsilon_0 n_1 n_2 n_3} I_1$$

$$g = \sqrt{\frac{\Delta k^2}{4} + \Gamma^2}$$

- Largest efficiency → Smallest g → $\Delta k = 0$ **Phase matching**

Example 2: Parametric amplification

- Boundary conditions:
  - ✓ Negligible depletion of $A_3(z)$: $\frac{\partial A_3(z)}{\partial z} = 0$
  - ✓ No A_2 field: $A_2(0) = 0$

$$\omega_1 + \omega_2 = \omega_3$$

$$I_1(L) = I_{10}\left\{1 + \left[\frac{\Gamma}{g}\sinh(gL)\right]^2\right\} \simeq I_{10}\left(\frac{\Gamma}{g}\right)^2 \frac{e^{2gL}}{4}$$

$$I_2(L) = I_{10}\frac{\omega_2}{\omega_1}\left[\frac{\Gamma}{g}\sinh(gL)\right]^2$$

$$\Gamma^2 = \frac{2d_{\mathrm{eff}}^2\omega_1\omega_2}{c_0^3\varepsilon_0 n_1 n_2 n_3} I_3$$

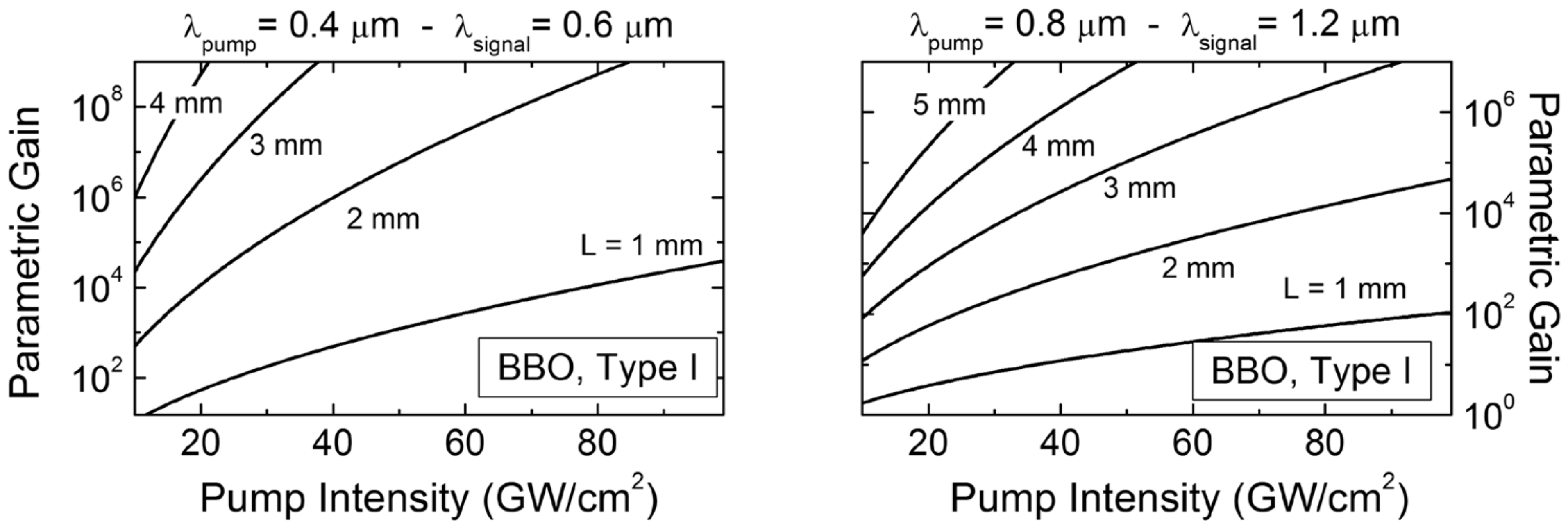
$$g = \sqrt{\Gamma^2 - \frac{\Delta k^2}{4}}$$

- Largest efficiency → Biggest g → $\Delta k = 0$ **Phase matching**

Parametric gain

- Signal intensity:

$$I_1(L) = I_{10}\left\{1 + \left[\frac{\Gamma}{g}\sinh(gL)\right]^2\right\} \simeq I_{10}\left(\frac{\Gamma}{g}\right)^2 \frac{e^{2gL}}{4} \qquad g = \sqrt{\Gamma^2 - \frac{\Delta k^2}{4}}$$



Meaning of Phase matching (I)

$$E(z,t)=\frac{1}{2}\{A_1(z)e^{j(\omega_1 t-k_1 z)}+A_2(z)e^{j(\omega_2 t-k_2 z)}+A_3(z)e^{j(\omega_3 t-k_3 z)}\}+\text{c.c.}$$

Field 3

Propagation velocity: $v_3=\dfrac{\omega_3}{k_3}$

$$\frac{\partial^2 P_{NL}(z,t)}{\partial t^2}=-\varepsilon_0 d_{eff}\omega_1^2 A_2^*(z)\cdot A_3(z)\cdot e^{j[\omega_1 t-(k_3-k_2)z]}$$
$$-\varepsilon_0 d_{eff}\omega_2^2 A_1^*(z)\cdot A_3(z)\cdot e^{j[\omega_2 t-(k_3-k_1)z]}$$
$$-\varepsilon_0 d_{eff}\omega_3^2 A_1(z)\cdot A_2(z)\cdot e^{j[\omega_3 t-(k_1+k_2)z]}+\text{c.c}$$

Source of field 3

Propagation velocity: $v_{P_{NL}}=\dfrac{\omega_3}{k_1+k_2}$

- P_{NL} efficiently deposits energy into ω_3 when they propagate with the same velocity:

$v_{P_{NL}}=v_3$ ⟹ $k_3=k_1+k_2$ ⟹ $\Delta k=k_3-k_2-k_1=0$ **Phase matching**

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Manley Rowe

- After suitable manipulation:

$$\begin{cases} \frac{\partial A_1}{\partial z} = -j\sigma_1 A_2^* A_3 \cdot e^{-j\Delta k z}, \\ \frac{\partial A_2}{\partial z} = -j\sigma_2 A_1^* A_3 \cdot e^{-j\Delta k z}, \\ \frac{\partial A_3}{\partial z} = -j\sigma_3 A_1 A_2 \cdot e^{j\Delta k z}, \end{cases}$$

$$\frac{dI_1}{dz} + \frac{dI_2}{dz} + \frac{dI_3}{dz} = 0 \qquad \text{I}$$

$$\frac{1}{\omega_1}\frac{\partial I_1}{\partial z} = \frac{1}{\omega_2}\frac{\partial I_2}{\partial z} = -\frac{1}{\omega_3}\frac{\partial I_3}{\partial z} \qquad \text{II}$$

I the sum of the energies of the three waves is conserved (in a lossless medium)

Intensity $I_i(z)$ corresponds to number of photons $N_i(z)/\Delta t$: $I_i(z) = \frac{N_i(z) \cdot \hbar\omega_i}{S\Delta t} c_0$

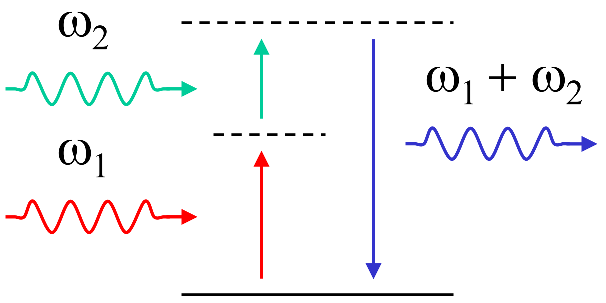
II

$$\frac{\partial N_1(z)}{\partial z} = \frac{\partial N_2(z)}{\partial z} = -\frac{\partial N_3(z)}{\partial z}$$

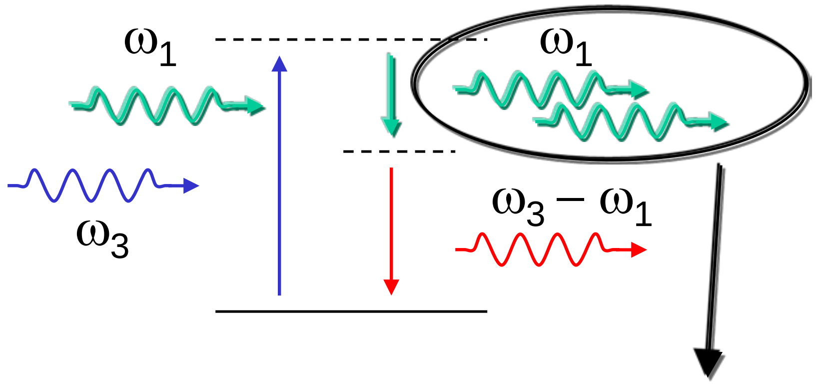
PHOTON CONSERVATION:
when one photon at ω_3 is created, two photons at ω_1 and ω_2 are simultaneously annihilated

Corpuscular view of second order processes

SFG - Sum Frequency Generation



DFG - Difference Frequency Generation



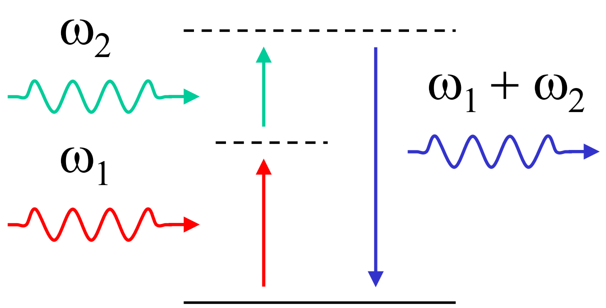
ω_1: signal

ω_2: idler

ω_3: pump

OPA - Optical Parametric Amplification

Meaning of Phase matching (II)



- Nonlinear interaction as a collision of collinear photons:

$$\omega_3 = \omega_1 + \omega_2 \Rightarrow \hbar\omega_3 = \hbar\omega_2 + \hbar\omega_1$$ Energy conservation

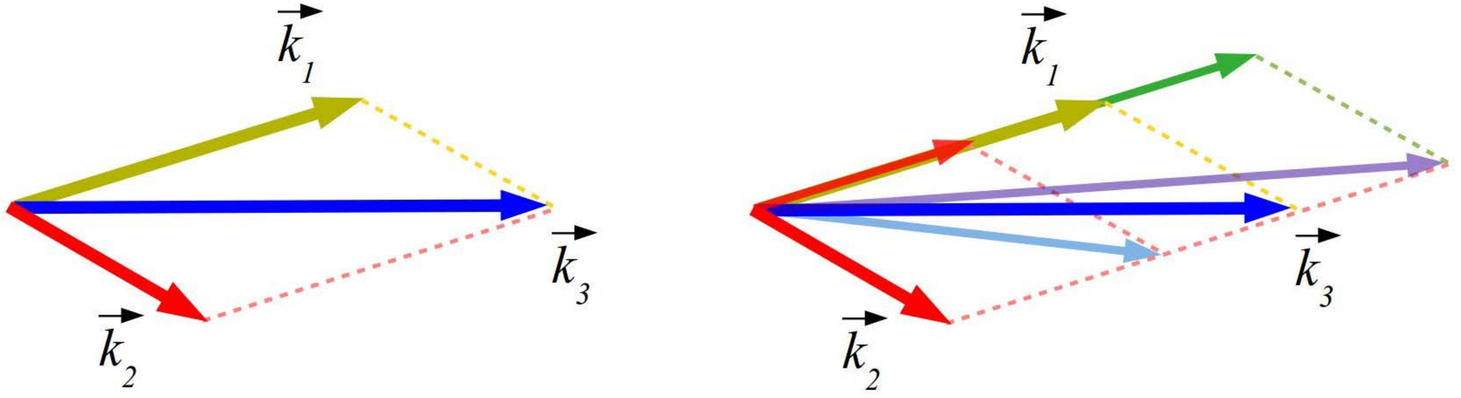
$$k_3 = k_1 + k_2 \Rightarrow \hbar k_3 = \hbar k_2 + \hbar k_1$$ Momentum conservation

- Can be also applied to noncollinear interactions: $\hbar\vec{k_3} = \hbar\vec{k_2} + \hbar\vec{k_1}$

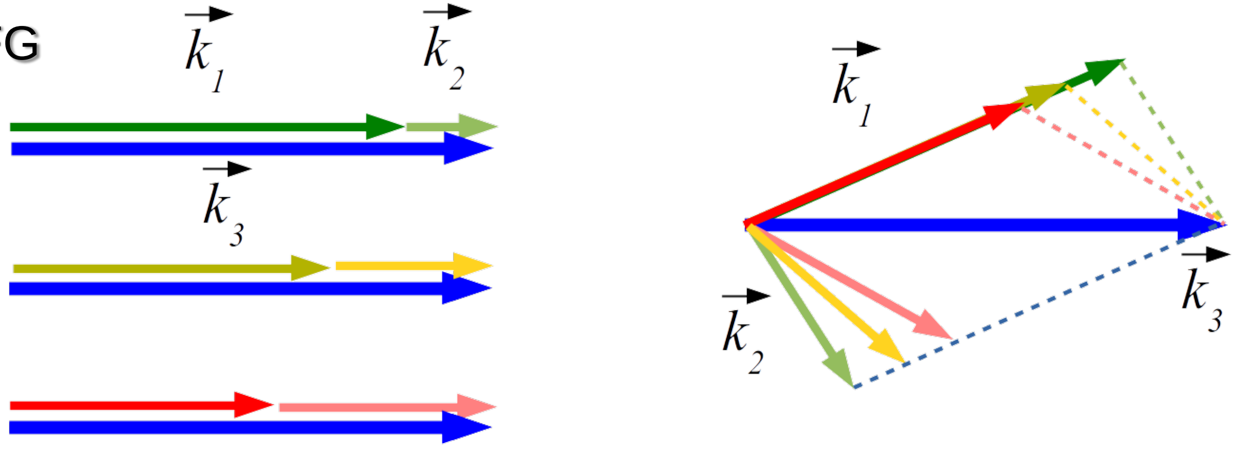
Extension to non-collinear interactions

$$\hbar\overrightarrow{k_3} = \hbar\overrightarrow{k_2} + \hbar\overrightarrow{k_1}$$

SFG



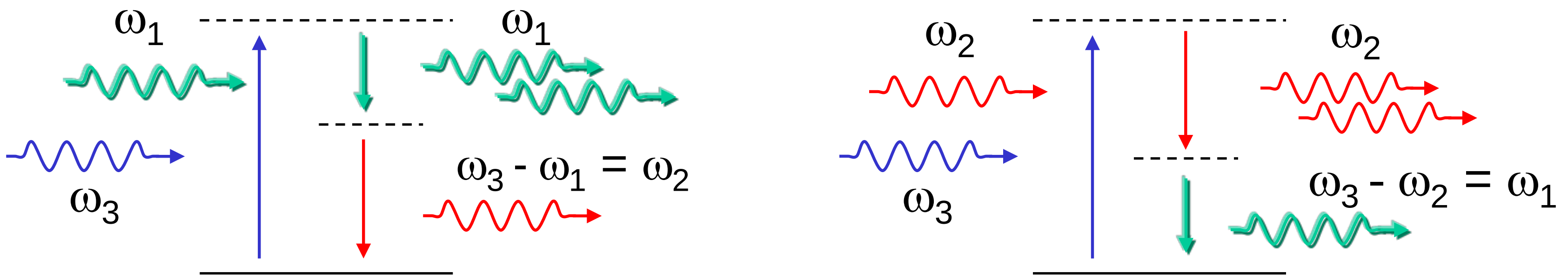
OPA / DFG



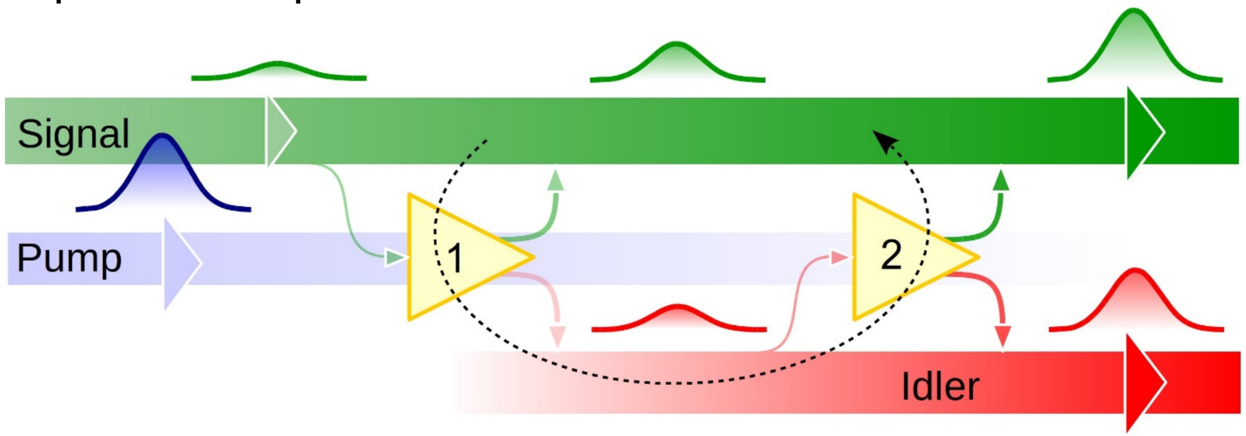
Why exponential gain?

$$I_1(L) = I_{10}\left\{1 + \left[\frac{\Gamma}{g}\sinh(gL)\right]^2\right\} \simeq I_{10}\left(\frac{\Gamma}{g}\right)^2 \frac{e^{2gL}}{4}$$

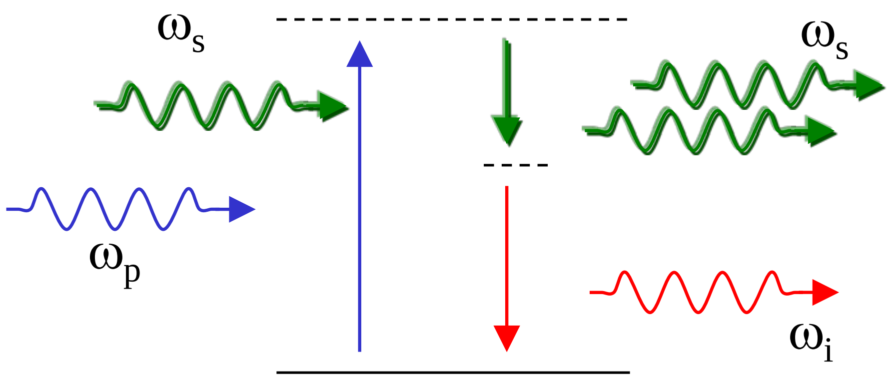
- Role of the idler beam...



- ... which gives rise to a positive loop.



Tuning range of an OPA



✓ Energy conservation

$$\hbar\omega_s + \hbar\omega_i = \hbar\omega_p$$

✓ Momentum conservation

$$\hbar\vec{k}_s + \hbar\vec{k}_i = \hbar\vec{k}_p$$

The tuning range of an OPA can be evaluated considering:

- Energy conservation:

$$\omega_s + \omega_i = \omega_p \quad \rightarrow \quad \boxed{\frac{\omega_s + \omega_i}{2} = \frac{\omega_p}{2}} \quad \rightarrow$$ Signal and idler: **symmetric** with respect to $\frac{\omega_p}{2}$

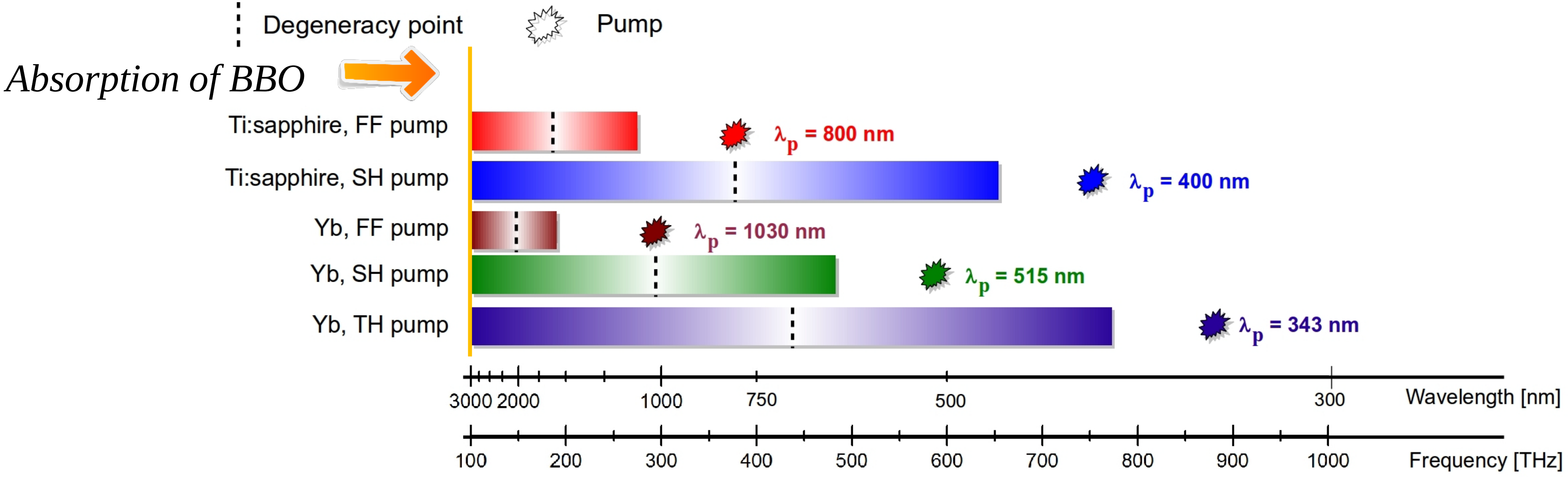
if $\omega_s = \omega_i \quad \rightarrow \quad \omega_s = \omega_i = \frac{\omega_p}{2}$ <u>Degeneracy point</u>

- Transmission range of the nonlinear crystal

Tuning range of an OPA

Example:

- ✓ *Nonlinear Crystal*: **BBO:** absorbs at λ >3 μm (ν <100 THz)
- ✓ *Laser*: Ti:sa (800 nm) or Yb-doped (1030 nm)



C. Manzoni and G. Cerullo, "Design criteria for ultrafast optical parametric amplifiers", J. Opt. 18, 103501 (2016)

Outline

- Turn-key sources of ultrashort pulses
- Nonlinear processes: wave equations
  - ✓ General equation
  - ✓ Second order processes
  - ✓ Coupled nonlinear equations
  - ✓ Meaning of phase matching (I)
- Corpuscular view of second order processes
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How to get phase matching?

- Phase matching requires $k_1 + k_2 = k_3$ equivalent to $\omega_1 n_1 + \omega_2 n_2 = \omega_3 n_3$
- In a medium with normal dispersion $(dn/d\omega > 0)$:

  $\omega_1 < \omega_2 < \omega_3$ have refractive index $n_1 < n_2 < n_3$

- Phase matching can be written as

$$\omega_1 n_1 + \omega_2 n_2 = (\omega_1 + \omega_2) n_3 \Rightarrow \underbrace{\omega_2 (n_2 - n_3)}_{<0} = \underbrace{\omega_1 (n_3 - n_1)}_{>0}$$

no phase matching in isotropic bulk materials

GENERATION OF OPTICAL HARMONICS*

P. A. Franken, A. E. Hill, C. W. Peters, and G. Weinreich
The Harrison M. Randall Laboratory of Physics, The University of Michigan, Ann Arbor, Michigan
(Received July 21, 1961)

The development of pulsed ruby optical masers[1,2] has made possible the production of monochromatic (6943 A) light beams which, when focussed, exhibit electric fields of the order of 10^5 volts/cm.

Table I. The square of the total p perpendicular to the direction of propagation of light through crystalline quartz.

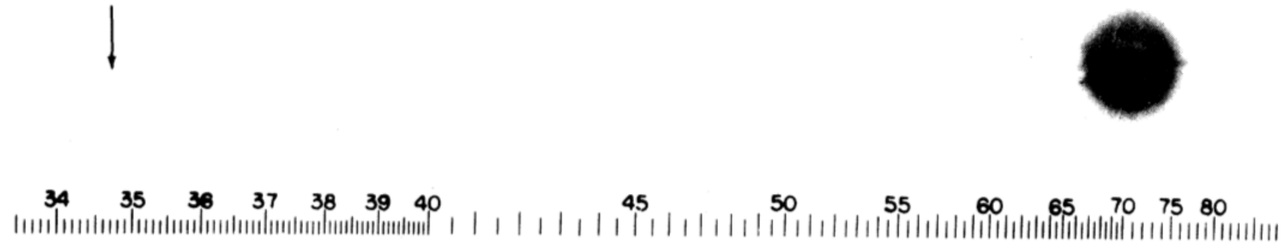


FIG. 1. A direct reproduction of the first plate in which there was an indication of second harmonic. The wavelength scale is in units of 100 A. The arrow at 3472 A indicates the small but dense image produced by the second harmonic. The image of the primary beam at 6943 A is very large due to halation.

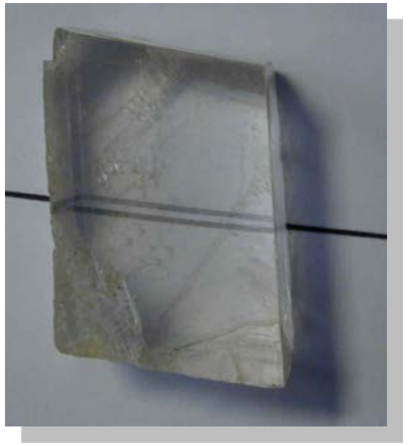
that second harmonic intensities as high as a fraction of a percent of the fundamental could be achieved.

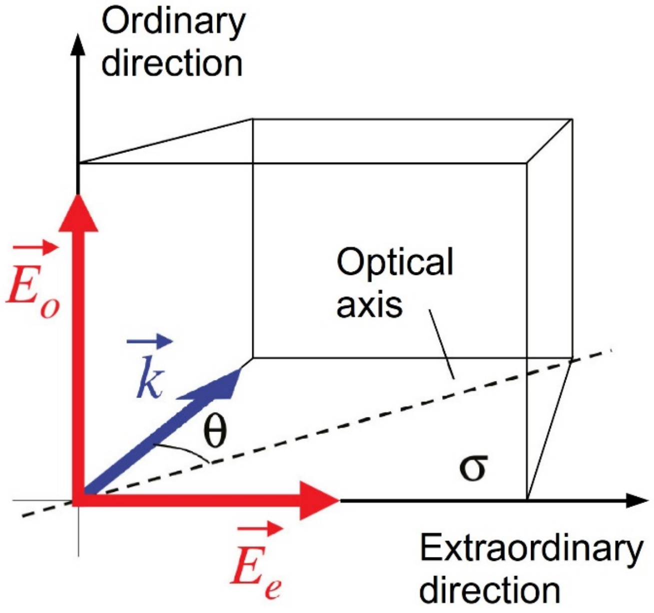
In the experiments we have used a commercially available ruby optical maser[4] which produces approximately 3 joules of 6943A light in a one-millisecond pulse. This light is passed through

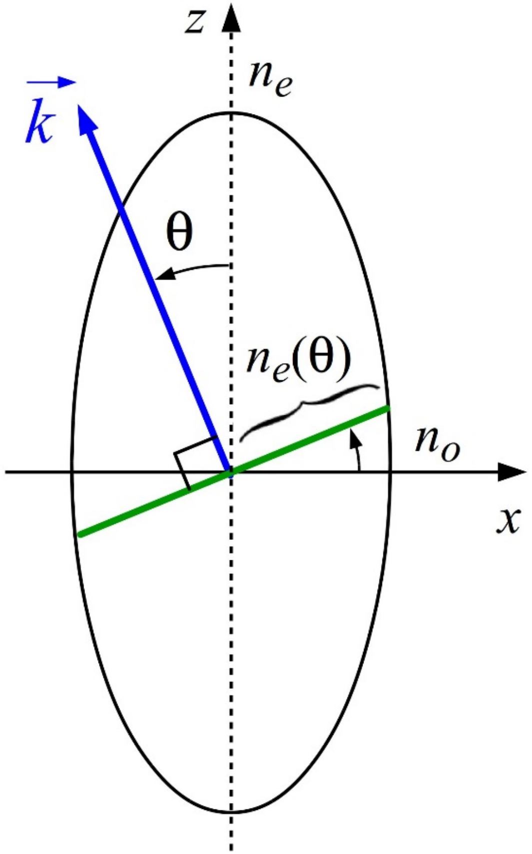
us to believe that the order of 10^{11} second harmonic photons were generated within the quartz sample per pulse.

The production of a second harmonic should be observable in isotropic materials such as glass if a strong bias field were applied to the sample. This bias could be oscillatory, thus

Solution: Birefringent crystals







o: ordinary axis

n_o , n_{go} , v_{go}

e: extraordinary axis

n_e , n_{ge} , v_{ge}

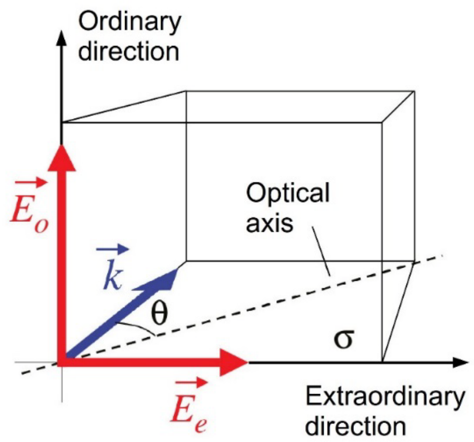
- n_e depends on θ:

$$\frac{1}{n_e(\theta)^2} = \frac{\cos^2\theta}{n_o^2} + \frac{\sin^2\theta}{n_e^2}$$

Interaction types

- $\omega_1 < \omega_2 < \omega_3$ can have different polarizations:

Type	ω_3 extraordinary	ω_3 ordinary
Type 0	eee	ooo
Type I	ooe	eeo
Type II	eoe	eoo
	oee	oeo



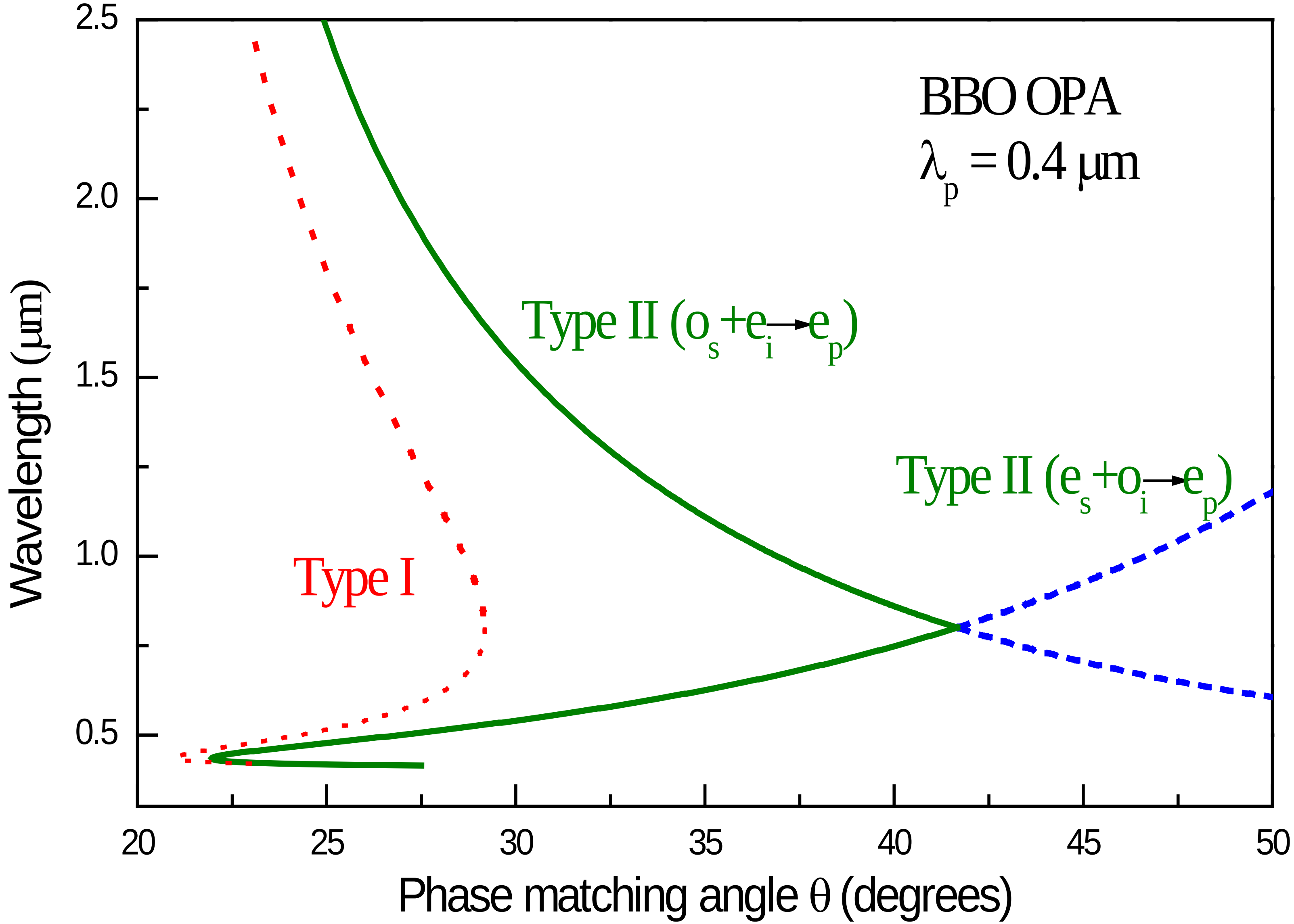
- Finding the phase-matching condition *means*:

  calculating, for a given Type, the angle θ that satisfies $\omega_1 n_1 + \omega_2 n_2 = \omega_3 n_3$

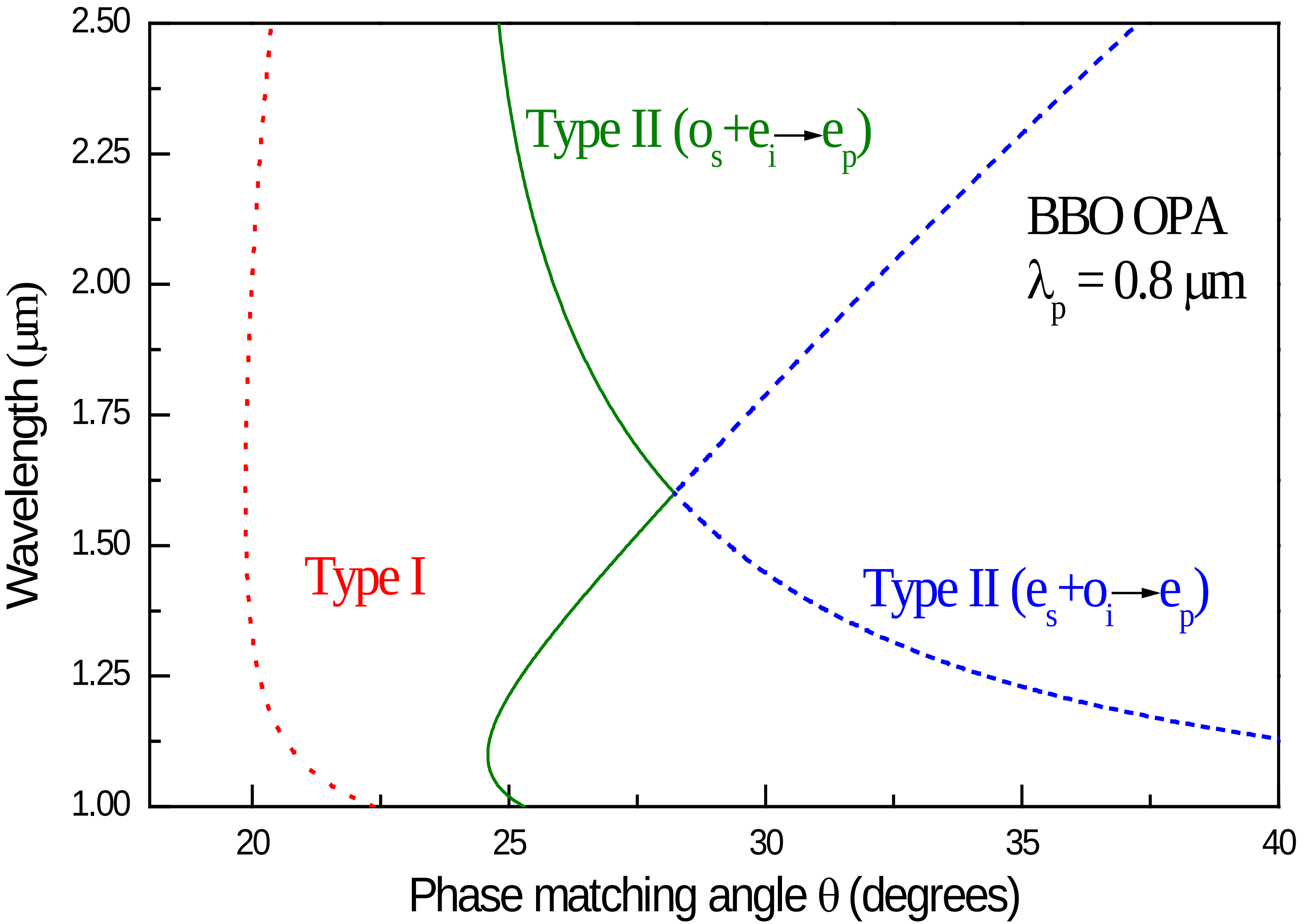
- When 2 fields are extraordinary: θ to be found numerically

Dmitriev V G, Gurzadyan G G, Nikogosyan D N and Lotsch H K V, Optics of nonlinear crystals: Handbook of Nonlinear Optical Crystals, Springer Series in Optical Sciences vol 64 (1999)

Example 1: Phase matching curves of a visible OPA



Example 2: Phase matching curves of an IR OPA



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Broadband gain: general calculation

- Broadband phase-matching: Δk small over a large range of frequencies

SFG

$$\Gamma^2 = \frac{2d_{eff}^2 \omega_2 \omega_3}{c_0^3 \varepsilon_0 n_1 n_2 n_3} I_1 \qquad g = \sqrt{\frac{\Delta k^2}{4} + \Gamma^2}$$

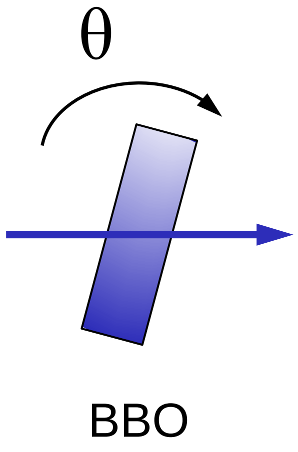
$$I_3(z) = \Gamma^2 \frac{\omega_3}{\omega_2} I_1 \cdot I_{20} \cdot \left| \frac{\sin(gz)}{g} \right|^2$$

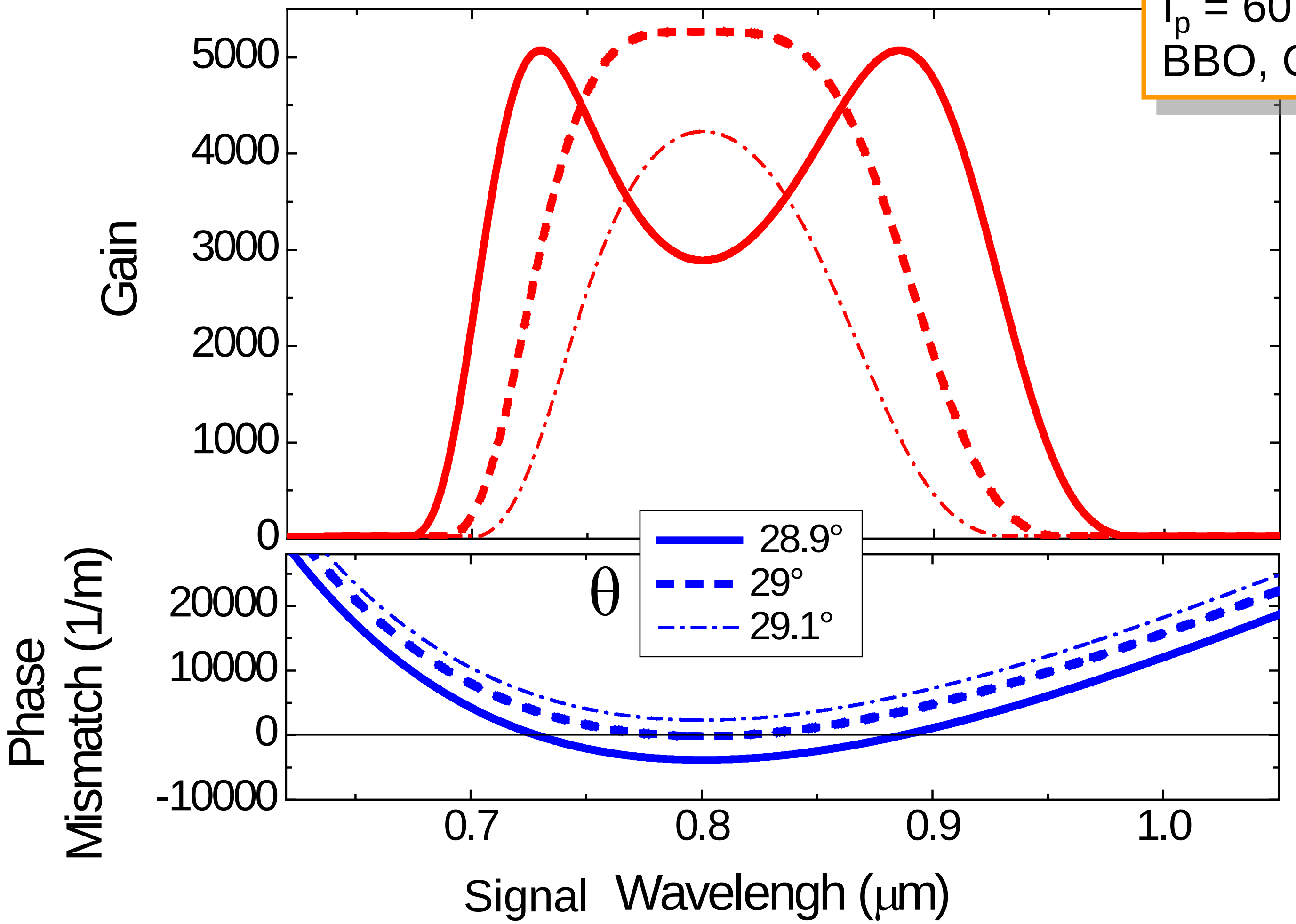
OPA

$$\Gamma^2 = \frac{2d_{\text{eff}}^2 \omega_1 \omega_2}{c_0^3 \varepsilon_0 n_1 n_2 n_3} I_3 \qquad g = \sqrt{\Gamma^2 - \frac{\Delta k^2}{4}}$$

$$I_1(L) = I_{10} \left\{ 1 + \left[\frac{\Gamma}{g} \sinh(gL) \right]^2 \right\} \simeq I_{10} \left(\frac{\Gamma}{g} \right)^2 \frac{e^{2gL}}{4}$$

Broadband gain: general calculation



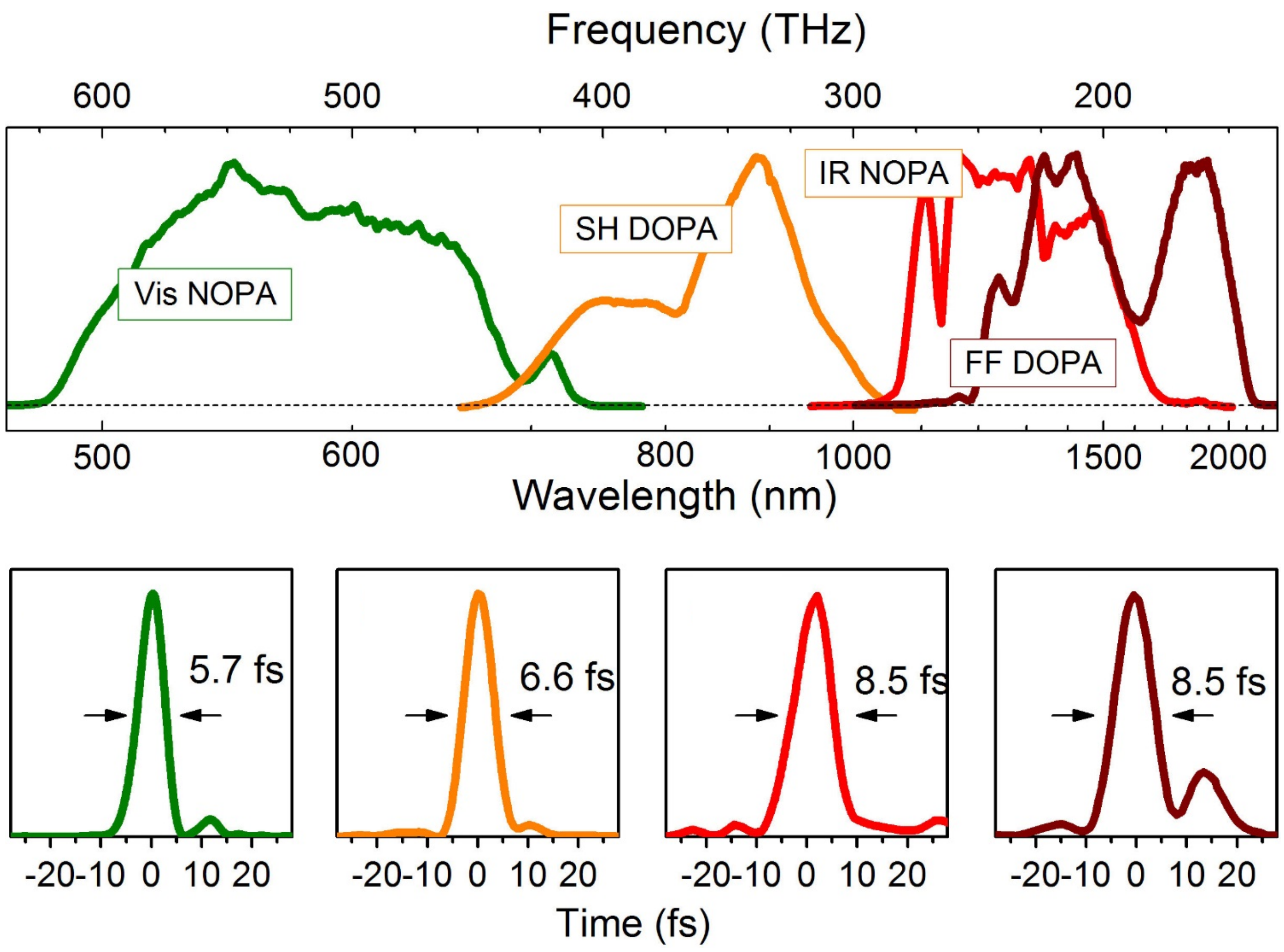


λ_p = 0.4 μm
I_p = 60 GW/cm^2
BBO, Collinear

$$g = \sqrt{\Gamma^2 - \frac{\Delta k^2}{4}}$$

$$I_1(L) \simeq I_{10} \left(\frac{\Gamma}{g}\right)^2 \frac{e^{2gL}}{4}$$

OPA pumped by Ti:Sapphire laser

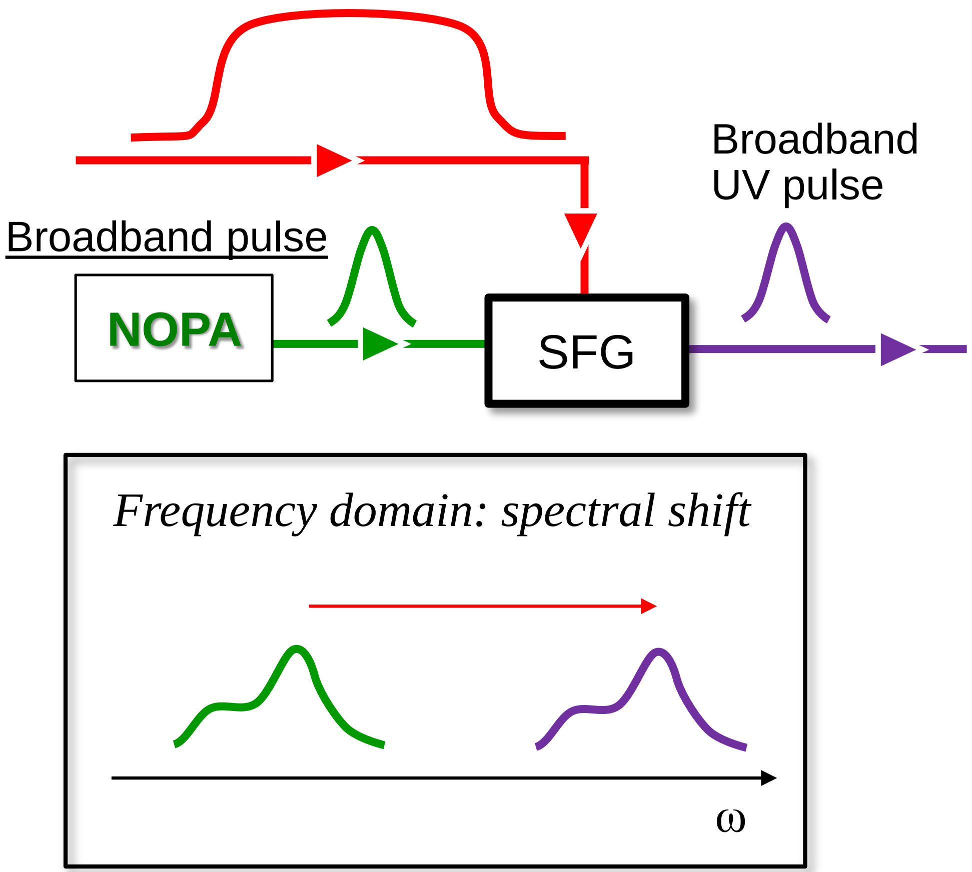


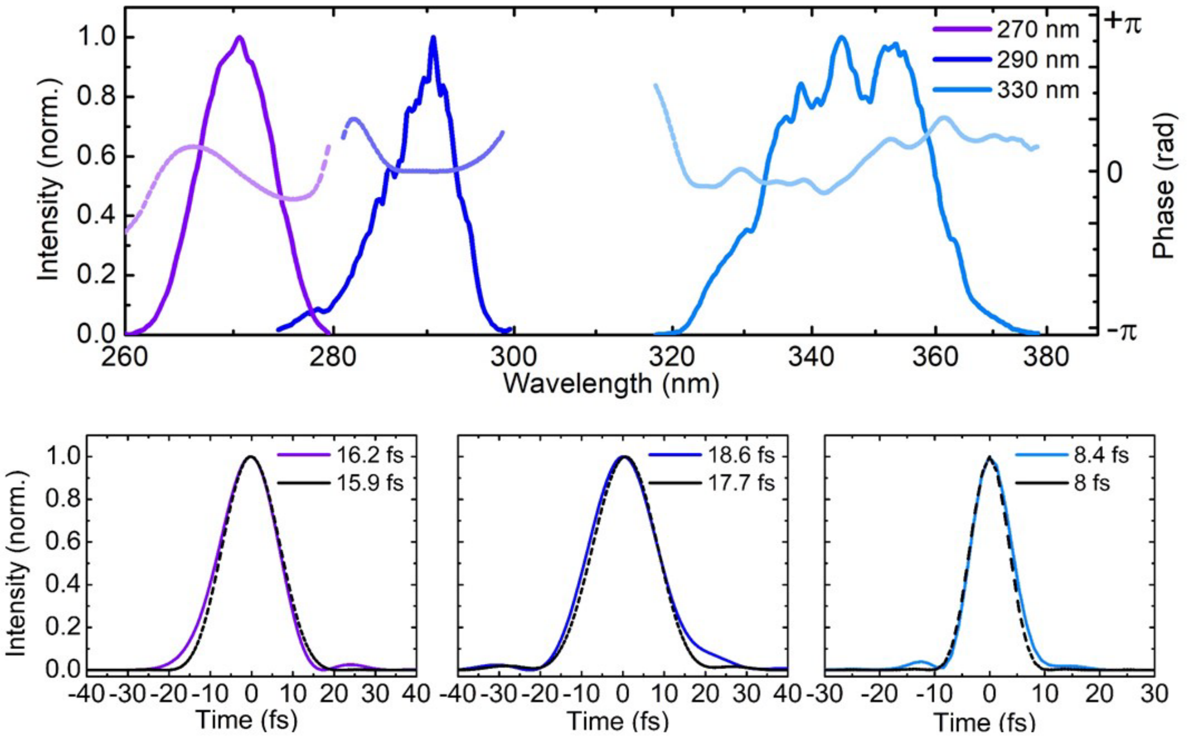
C. Manzoni, D. Polli and G. Cerullo, Rev. Sci. Instr. **77**, 023103 (2006)

D. Brida *et al.*, J. Opt. A **13**, 013001 (2010)

Ti:sa - Generation of UV pulses

- The idea: **sum frequency generation** between **broadband** and **narrowband** pulses

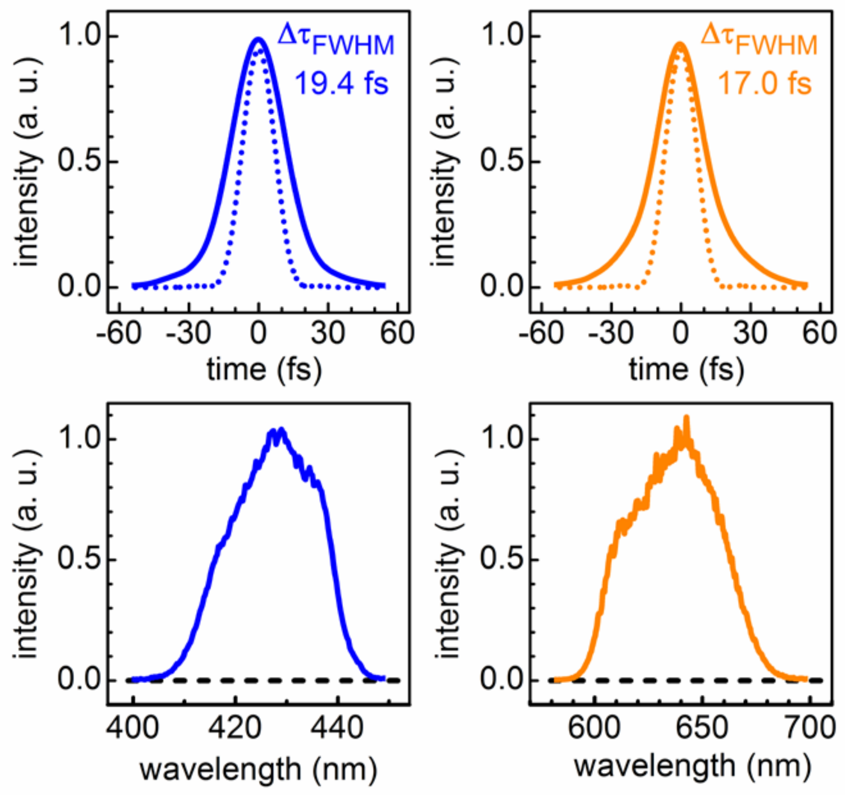




R. Borrego-Varillas et al., Appl. Sci. 8, 989 (2018)

R. Borrego Varillas *et al.*, Opt. Lett. **39**, 3849-3852 (2014)

OPA pumped by Yb laser (2ω seeded 3ω pumped)



- Tuning from **395-650nm**
- **1.2 µJ** pulse energy in the maximum
  500 nJ over the tuning range
- **Sub-20 fs** pulses and
  sub-10 fs Fourier limits

Courtesy of prof. E. Riedle

"Sub-20 fs µJ-energy pulses tunable down to the near-UV from a 1 MHz Yb-fiber laser system," M. Bradler and E. Riedle, Opt. Lett. **39**, 2588 (2014).

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Generation of Ultrashort Pulses:
Basic concepts and nonlinear optics techniques

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OSA Ultrafast Optical Phenomena Technical Group Online Workshop