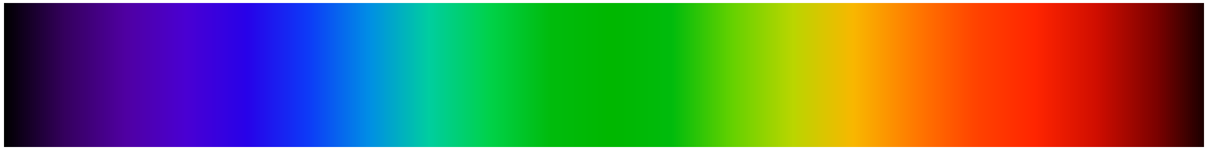
Constructing an Optical Parametric Amplifier (OPA) to allow for wavelength tuning over the visible range for PULSAR



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U.S. DEPARTMENT OF ENERGY

What is an OPA?

Arrangement of **optical elements** which, using **Nonlinear Optics**, allows for a pump laser to **amplify** a range of wavelengths thus creating a laser source of tunable wavelength

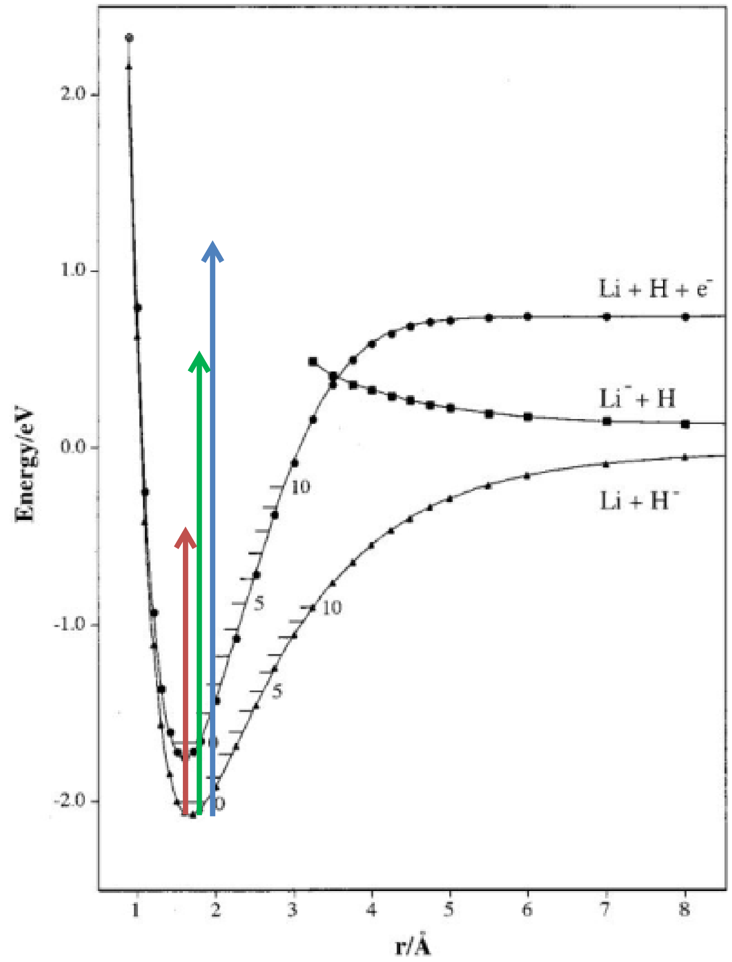
The goal for our specific OPA is for the tunability to be roughly over the **visible** spectrum (390-700nm)

Why do we want an OPA?

Current capabilities are 790nm or 395nm

One such OPA experiment is:

- LiH^{-} Dissociation paths



D.T. Chang *et al.*, The Journal of Chemical Physics 117, 5757 (2002)

Nonlinear Optics

In linear optics:

$$\boldsymbol{P} = \epsilon_0 \mathrm{X}^{(1)} \boldsymbol{E}$$

In nonlinear optics:

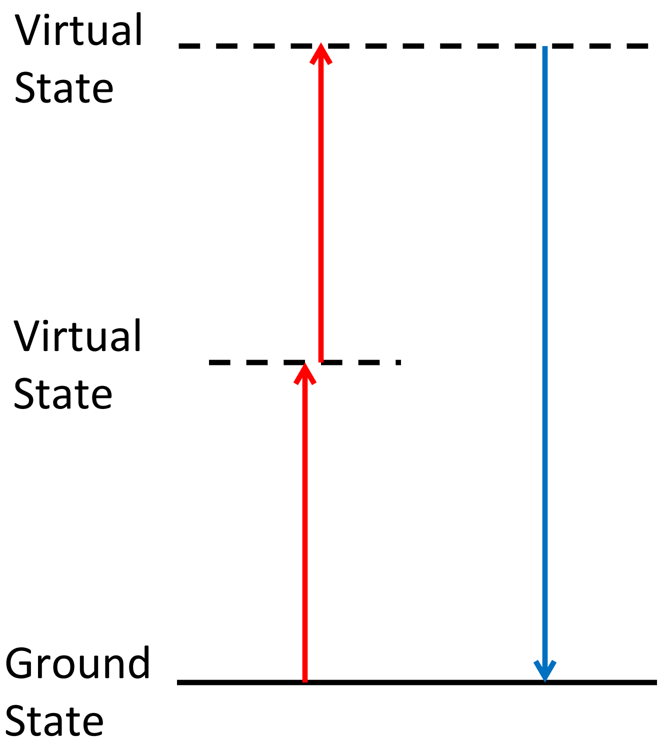
$$\boldsymbol{P} = \epsilon_0 \left(\mathrm{X}^{(1)} E + \mathrm{X}^{(2)} E^2 + \ \ldots \right) \widehat{\boldsymbol{E}}$$

Usually $\mathrm{X}^{(2)}$ is small enough that we stay in the linear optics regime
However, with high peak intensity we access non-linear effects

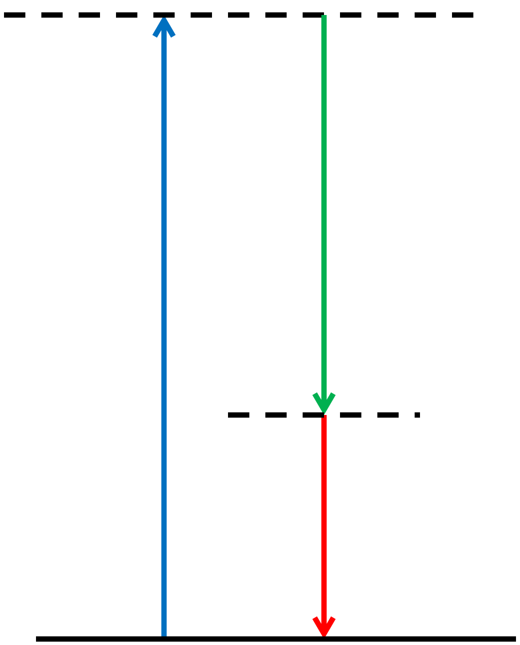
These effects can be unintuitive and useful

Nonlinear Processes

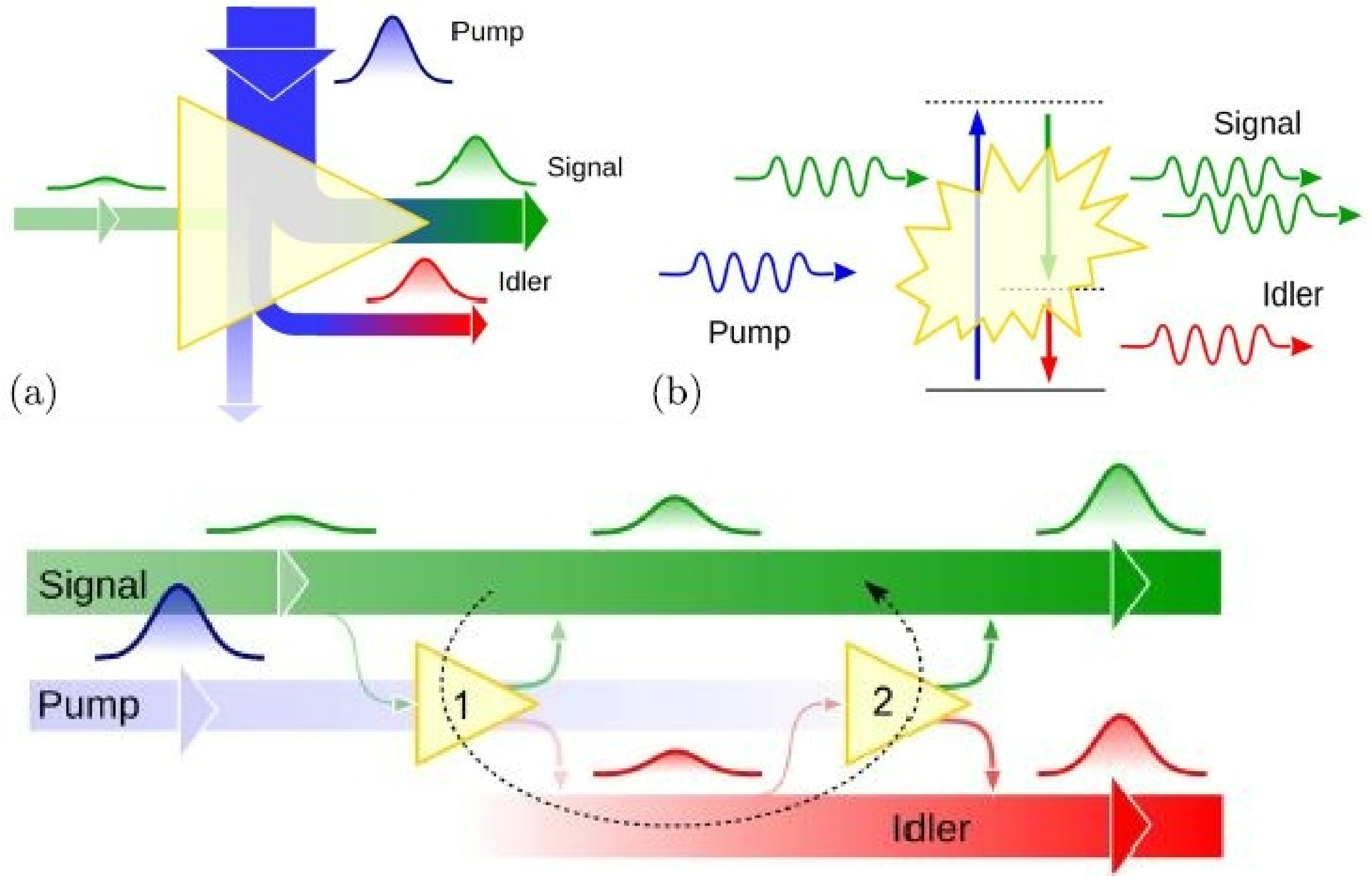
Second Harmonic Generation



Difference Frequency Generation



OPA process



Positive feedback loop leads to efficient amplification

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Phase Matching

Conservation of Momentum

$$\hbar k_p = \hbar k_s + \hbar k_i$$

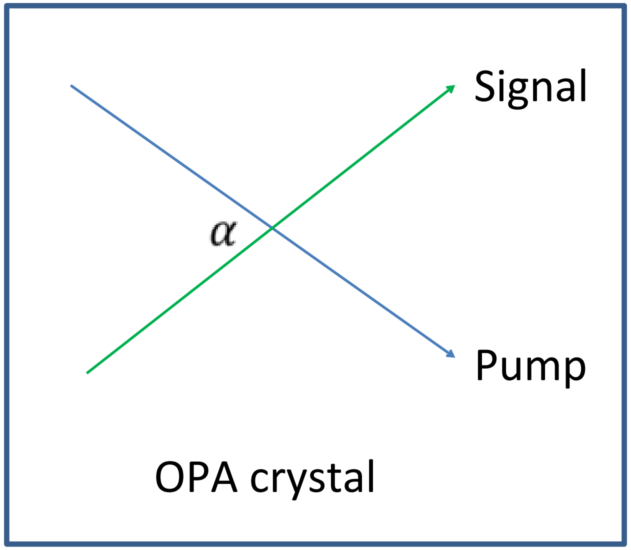
For photons this simplifies to

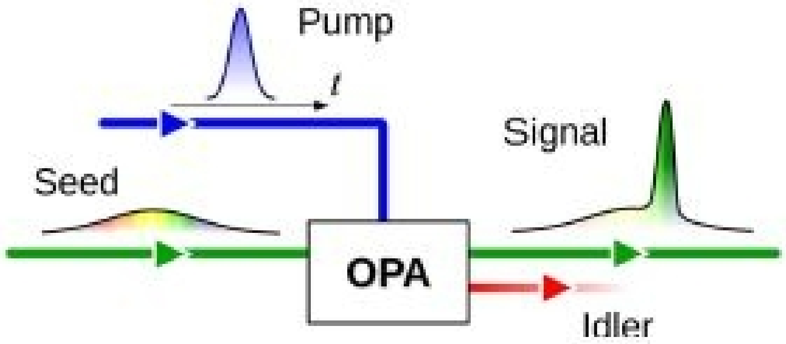
$$\frac{n_p}{\lambda_p} = \frac{n_s}{\lambda_s} + \frac{n_i}{\lambda_i}$$

Index of refraction is also a function of wavelength
We can achieve phase matching for a wavelength through the use of a birefringent crystal and a specific cut angle

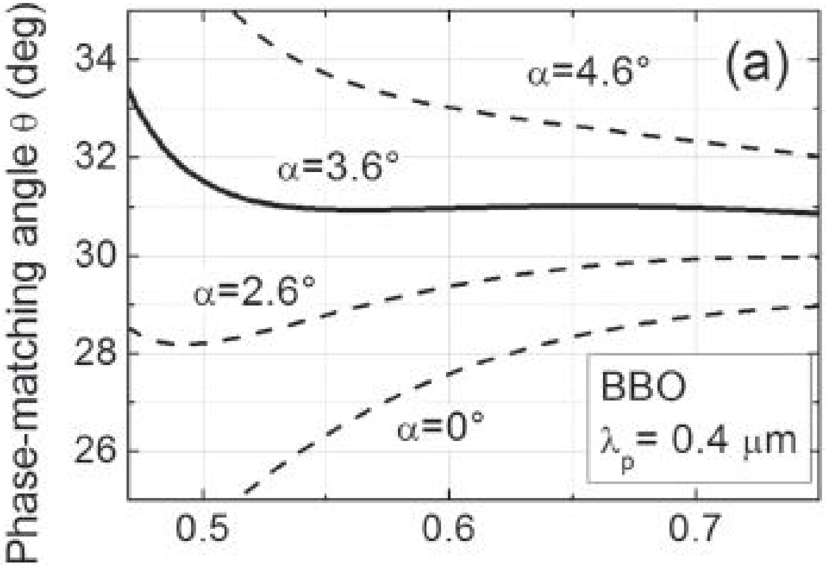
Non-Collinear Phase Matching

Signal and Pump crossing non-collinearly





Broadband phase-matching can be achieved with specific crossing angle



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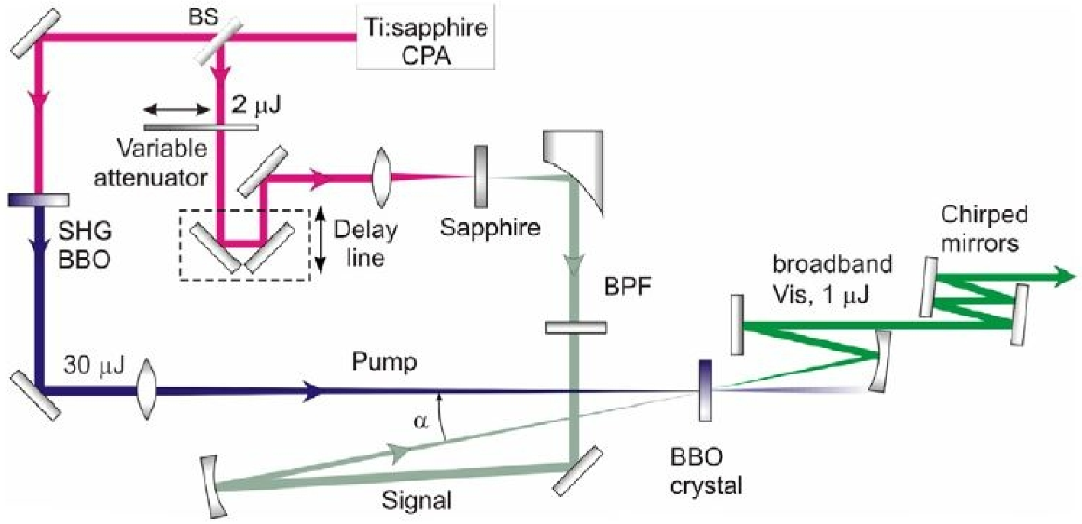
From Theory to Design

Known Technology: We can look to what others have done

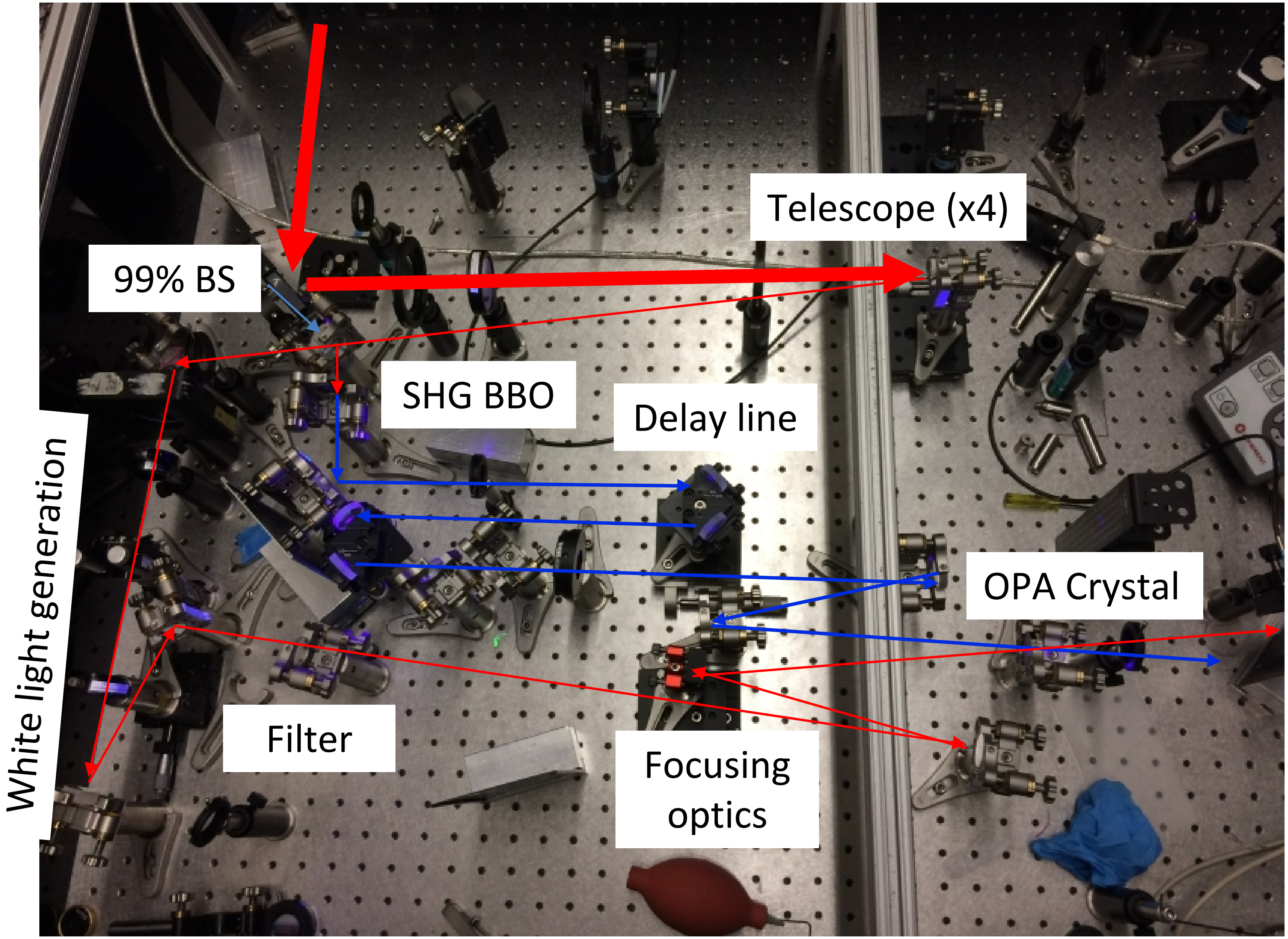


Make major design decisions

Once we have an overarching design we can start ordering the optical elements that we will need

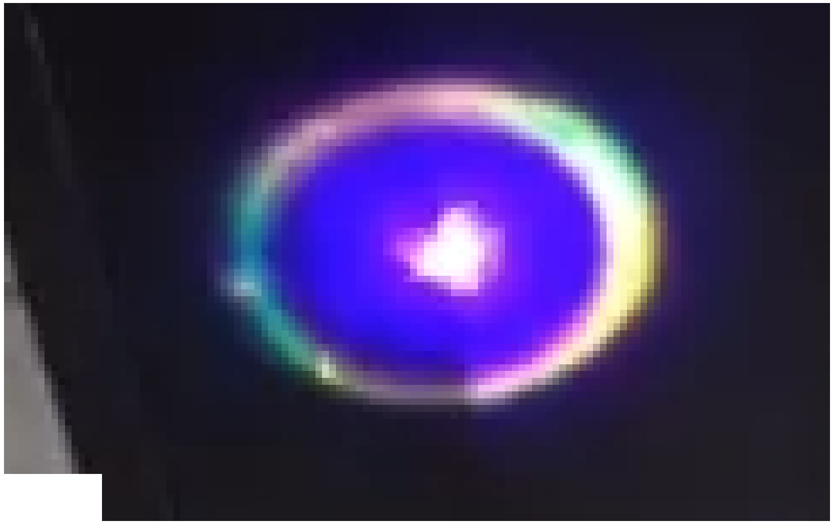
This was a long process with many minor design decisions

Our Setup

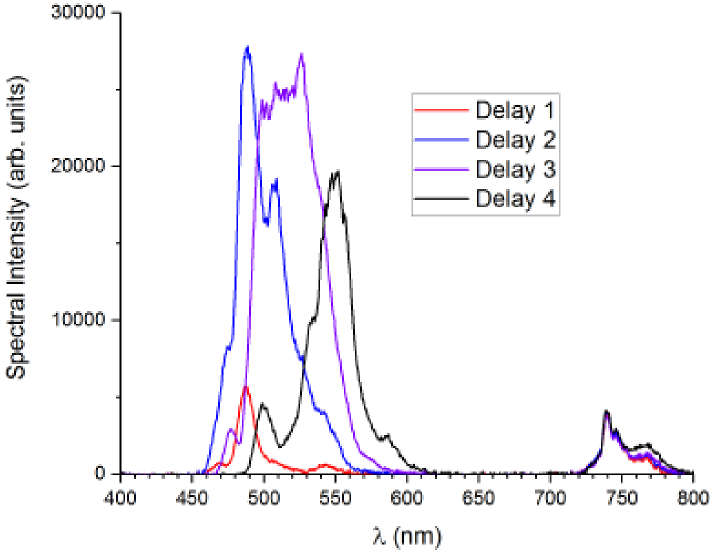

99% BS
Telescope (x4)
SHG BBO
Delay line
White light generation
OPA Crystal
Filter
Focusing optics

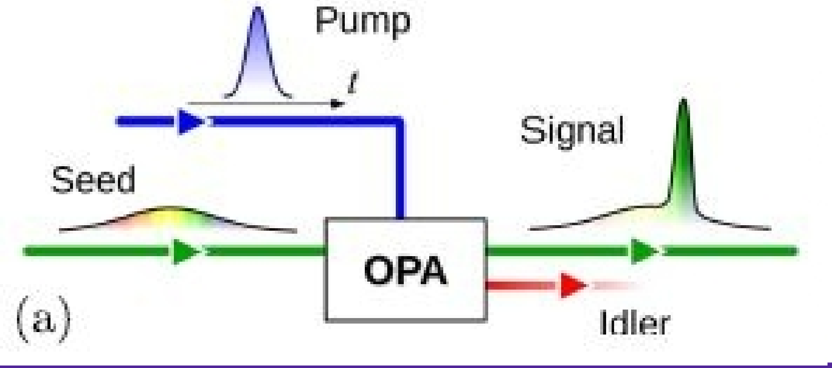
Results

Video as SHG delay is varied



Output spectra with various delays





Known Problems

1 Spatial Chirp –

can be seen in the beam on our table and in the PULSAR room

2 Focusing Optics –

Missed ordering a mount. This affects the quality of our signal beam

3 Various other changes in the exact optics arrangement

Future endeavors

- Optimize first stage of the OPA
- Build the second stage of the OPA
  for output stability
- Compression the output pulse in time
- Miniaturize the OPA as much as possible

Thank you!

Itzik Ben-Itzhak group

Itzik Ben-Itzhak
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Raju Pandiri

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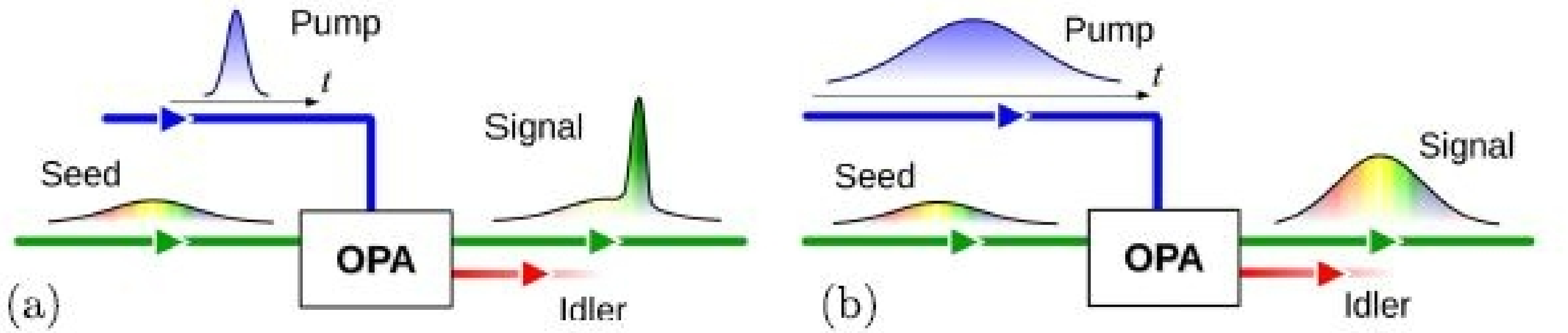

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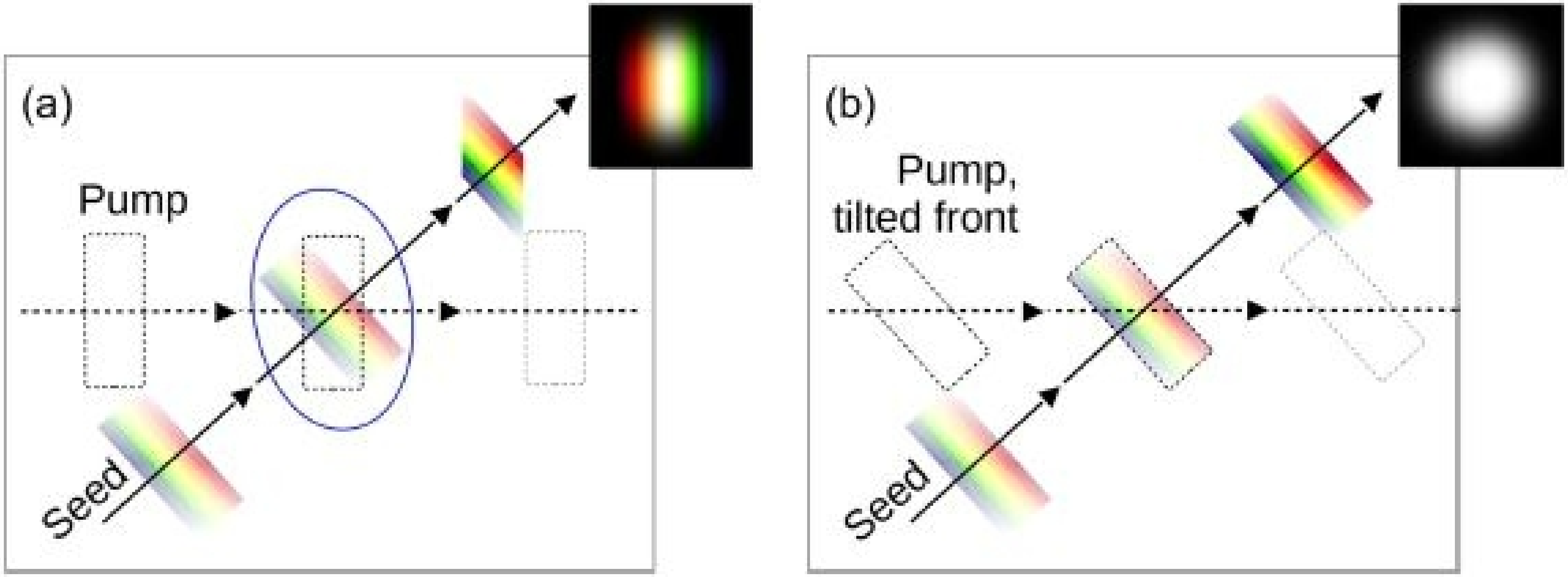
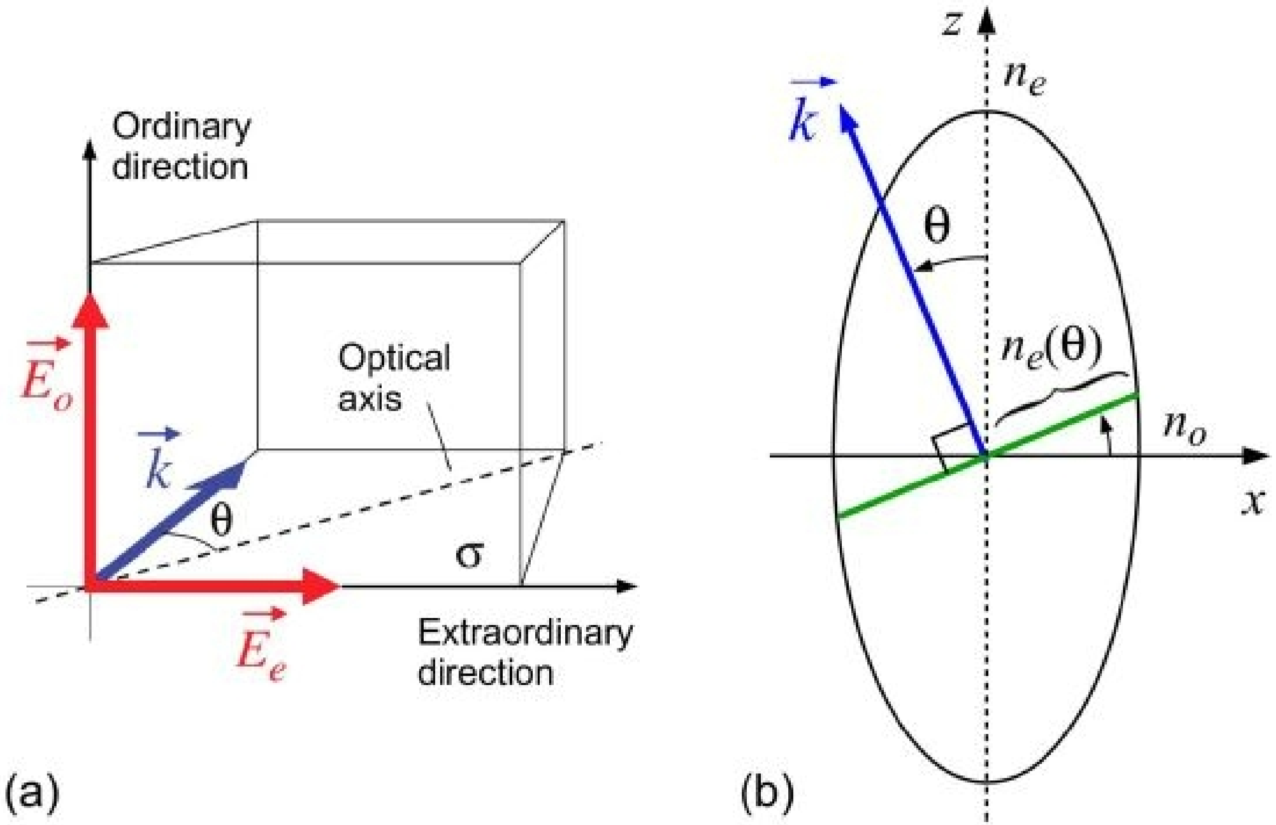

(a)
Pump
Seed
(b)
Pump,
tilted front
Seed



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

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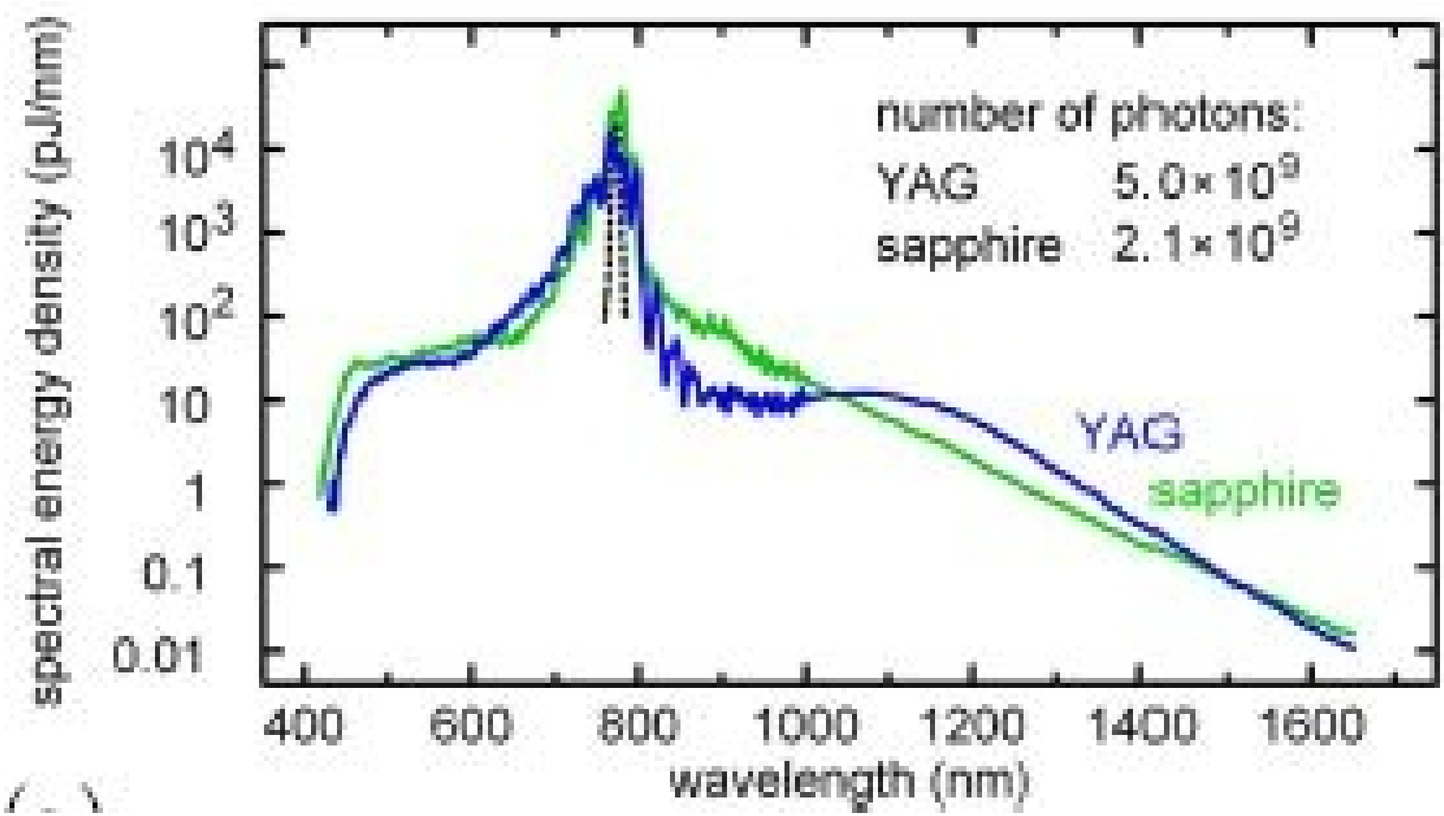

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