# Laser Beam Diagnostics

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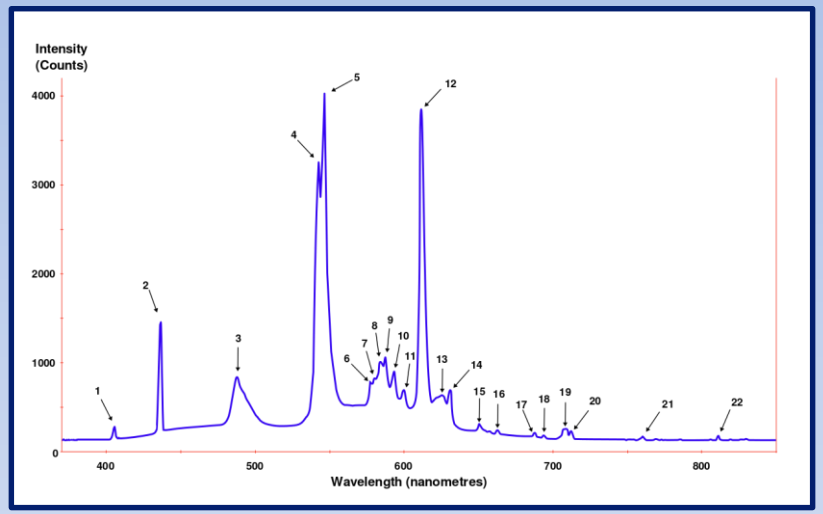
# Laser diagnostics: is it working?

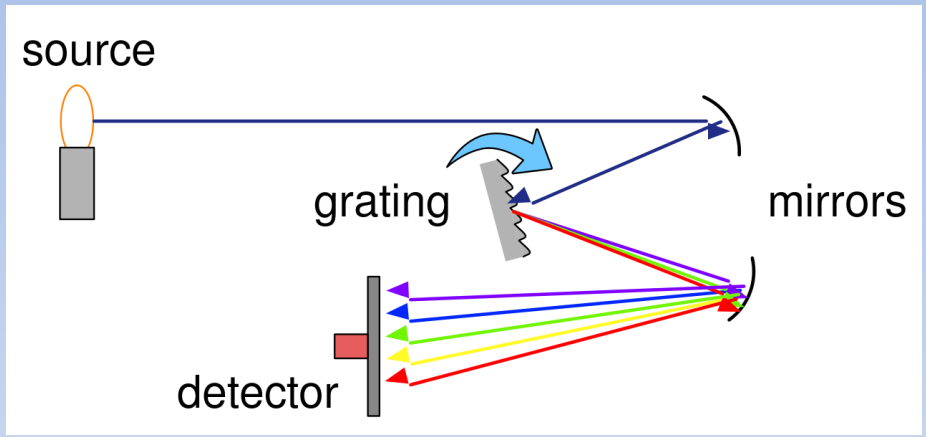
- What do you want to know?
  - Energy/power
  - Pulse duration, possibly including spectral phase
  - Spot size
  - Spatial jitter
  - Spectrum
  - Arrival time
  - Temporal jitter

- How often?
  - Once
  - Once a day
  - Every laser shot
  - Over a time series of shots?

# Spectrum

- Spectrometer – grating(s) to disperse frequency components, camera, recording medium
- Think about range, resolution, sensitivity




$$d(\sin\theta + \sin\alpha) = m\lambda$$

Can get convenient low resolution hand held spectrometers, often with fibre coupling
Imaging spectrometer is 2D – one spatial, one spectral axis.

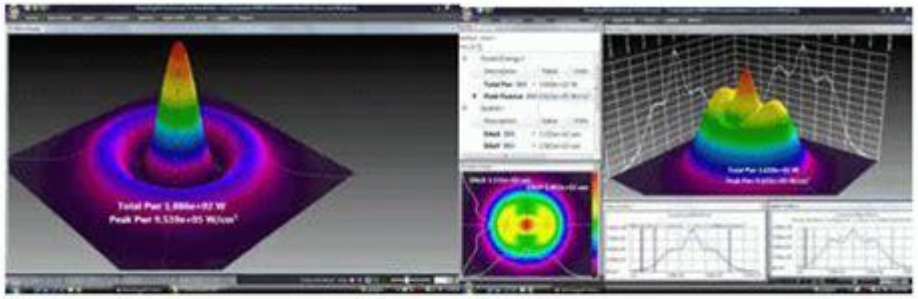
# Power/Energy

- Measure average power or individual pulse energy
- Typically use an energy head inserted into laser beam connected to meter
- Set correct wavelength and statistics
- Different types heads – semiconductor photodiode (generally low energy)
- Thermal heads for high power
- Check calibration


- Can put in laser beam directly
- Or take leakage through a mirror
- Calibrate transmission
- Damage – don't focus onto detector

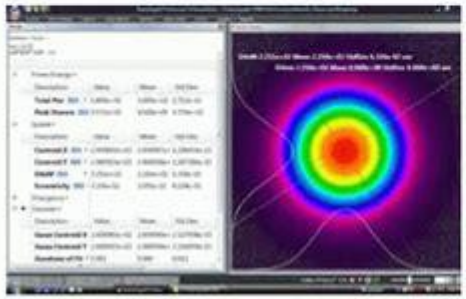
# Beam size & quality

Plenty of cameras available
Specialist beam profiling software

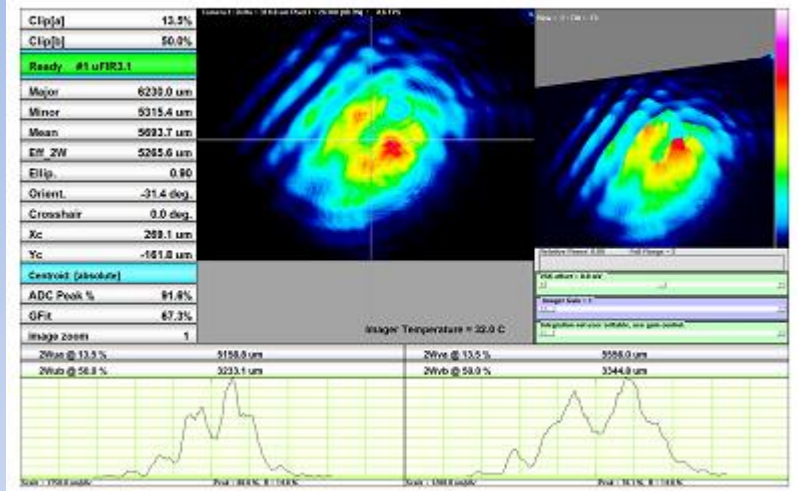


3d example of beam profile

Example with 2d/3d and 2d slices and results



2d example of beam profile



Issues – resolution:
Pixel size? Magnification?
Damage!

# Pulse duration measurement

Nanosecond or longer – measure electronically, photodiode + oscilloscope

Shorter than ~ 1ns not possible.

Picosecond & femtosecond pulses are the shortest technologically generated events
How do we measure them? Use the pulse itself!

To fully reconstruct the pulse need either:
Temporal amplitude and phase
Or spectral amplitude and spectral phase

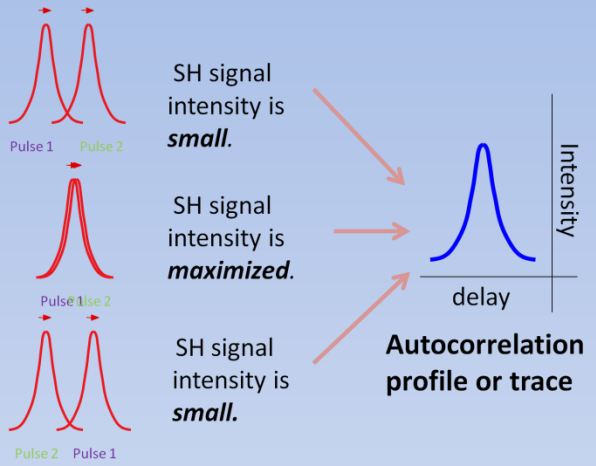
Can make estimates with less information

Translation: If you don't have a detector or modulator that is fast compared to the pulse width, you **CANNOT** measure the pulse intensity and phase with only linear measurements, such as a detector, interferometer, or a spectrometer.

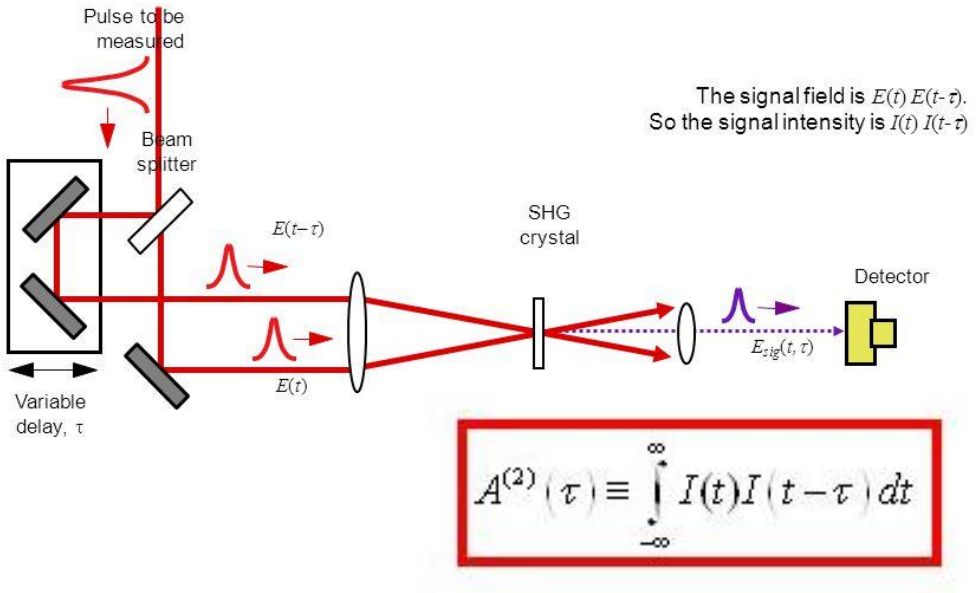
V. Wong & I. A. Walmsley, Opt. Lett. **19**, 287-289 (1994)
I. A. Walmsley & V. Wong, J. Opt. Soc. Am B, **13**, 2453-2463 (1996)

**We need a shorter event, and we don't have one.**
**But we do have the pulse itself, which is a start.**
**And we can devise methods for the pulse to gate itself using optical nonlinearities.**

# Intensity autocorrelation

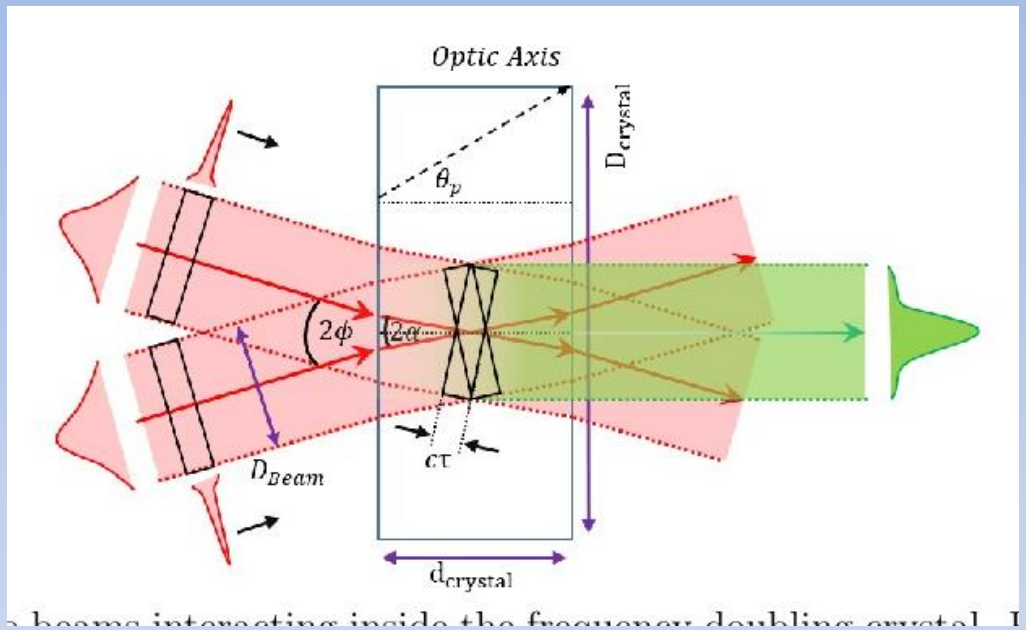


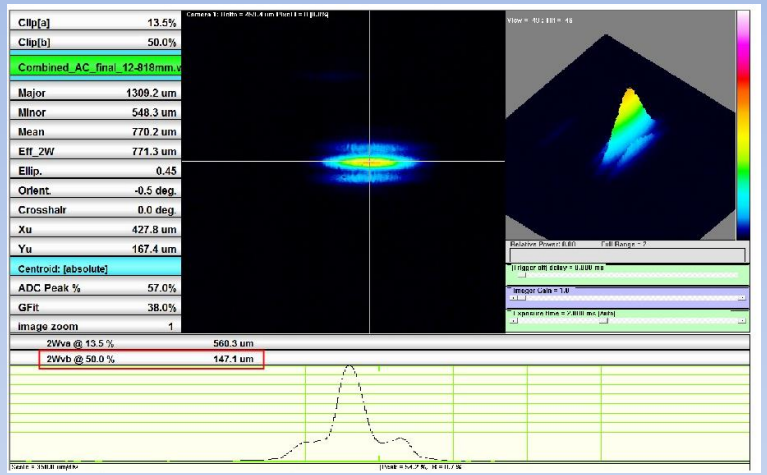

## Intensity Autocorrelator:




- Scan delay between two copies of pulse to be studied
- Slow detector measures intensity autocorrelation of the pulse
- Averages over many pulses & difficult for long (100s ps) pulses
- Must assume pulse shape to extract duration – doesn't measure phase

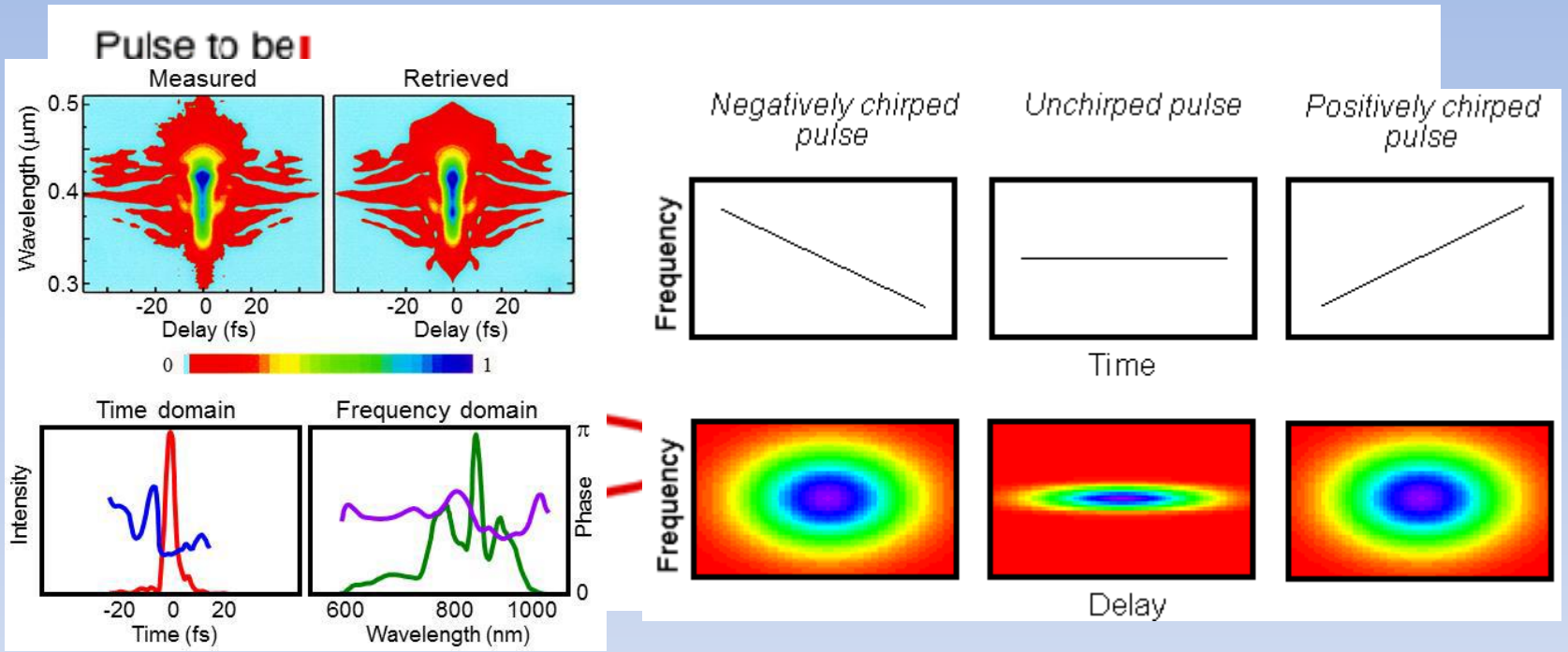
# Single shot autocorrelation




- The large diameter pulses cross in the crystal
- They map each other out in time
- Create a stripe of SHG light
- The width of the stripe is the autocorrelation
- Single shot technique really useful!

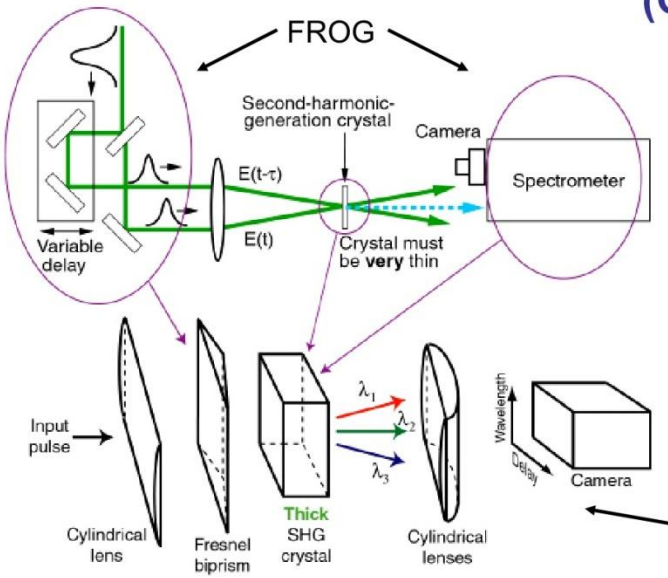
# FROG – frequency resolved optical gating




- Basically a spectrally resolved autocorrelation - how does that help?
- Have both frequency & time – spectrogram
- Can reconstruct the full pulse iteratively from this information

# GRENOUILLE

## GRating-Eliminated No-nonsense Observation of Ultrafast Incident Laser Light E-fields (GRENOUILLE)




2 key innovations:
A *single* optic that replaces the *entire* delay line,
and a *thick* SHG crystal that replaces *both* the thin crystal *and* spectrometer.

Patrick O'Shea, Mark Kimmel, Xun Gu and Rick Trebino, Optics Letters, 2001.

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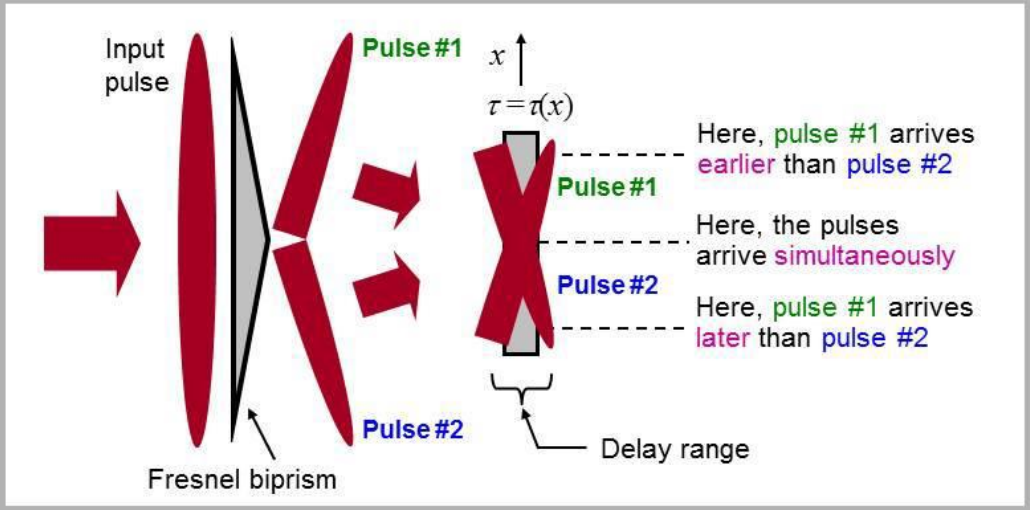
FROG still has a scanning delay stage – alignment issues
GRENOUILLE is a much simpler single shot version of FROG

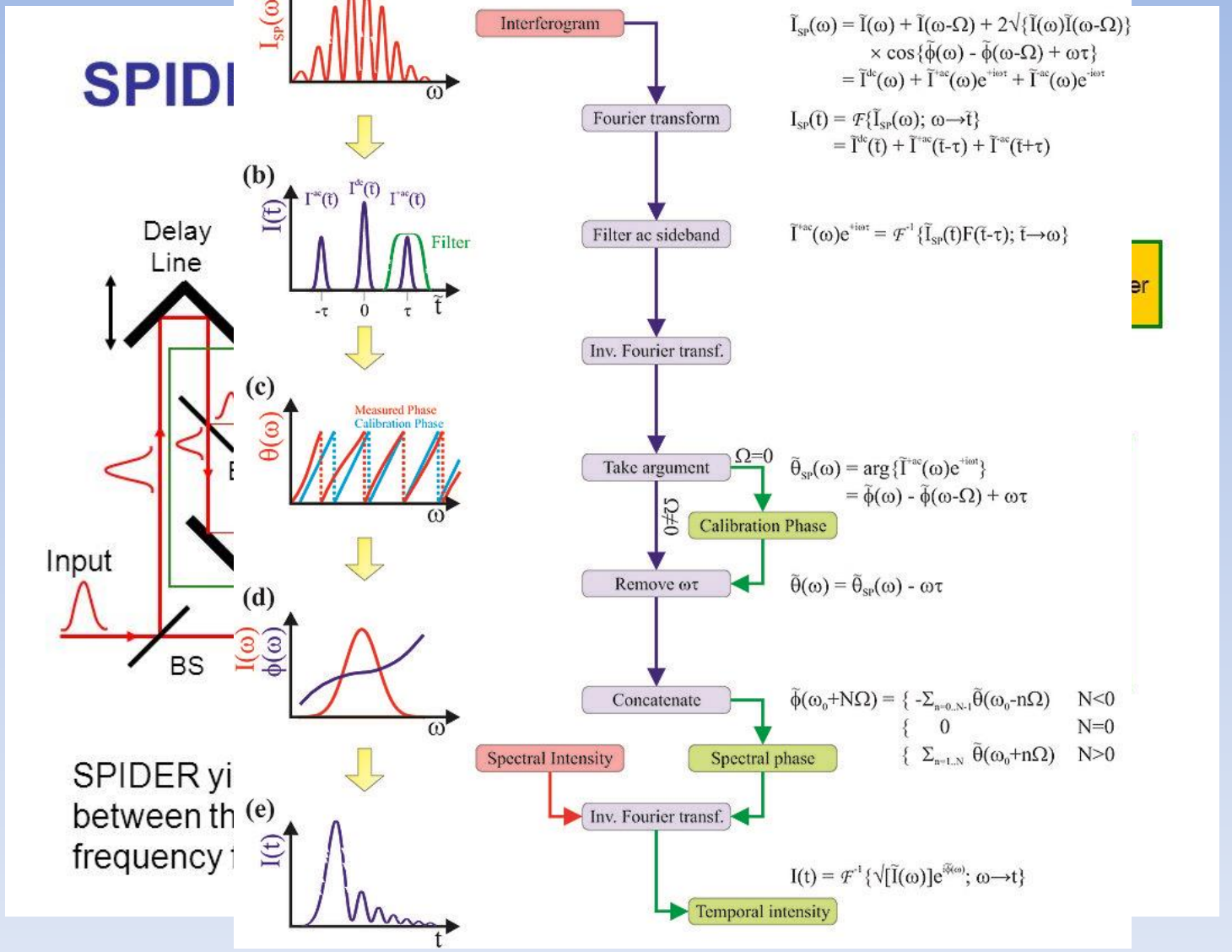
## The Fresnel biprism

Crossing beams at a large angle maps delay onto transverse position.




This achieves the entire range of delays for a single pulse and so yields an **alignment-free single-shot** measurement of a pulse.

# SPIDER


SPIDI
Delay Line
Input
BS
SPIDER yi
between th
frequency
(a)
(b)
(c)
(d)
(e)
Filter
Measured Phase
Calibration Phase
Interferogram
Fourier transform
Filter ac sideband
Inv. Fourier transf.
Take argument
Ω=0
Ω≠0
Calibration Phase
Remove ωτ
Concatenate
Spectral Intensity
Spectral phase
Inv. Fourier transf.
Temporal intensity

# Help, there's no signal!

What's going wrong??

Is the detector switched on?
Is it connected to power?
To the scope?
To the computer?
Is the computer on the network?
Has someone unplugged it?

Is the laser on?
Blocked somewhere?
Is the laser/detector too heavily attenuated?
Has someone moved the detector?
Is someone standing in the way?
Has the interlock tripped?
Is the laser misaligned?

Is the detector for the right wavelength?
For the right energy range?
Out of range?
Is it the right software?
The right version of the software?

Is the detector triggered?
Is the scope triggered?
Has the computer frozen?
Can you not read the computer screen through laser goggles?