Femtosecond Pulse Sequence Processing Using a Double-Passed Arrayed Waveguide Grating

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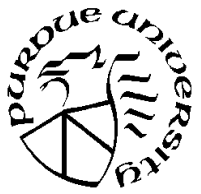
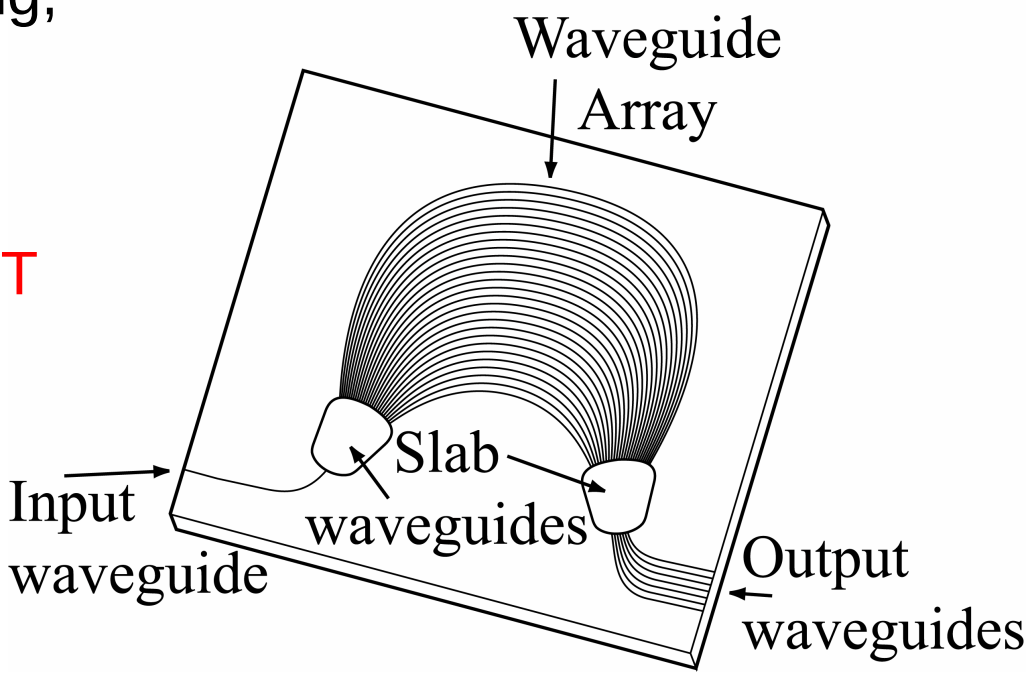


Motivation

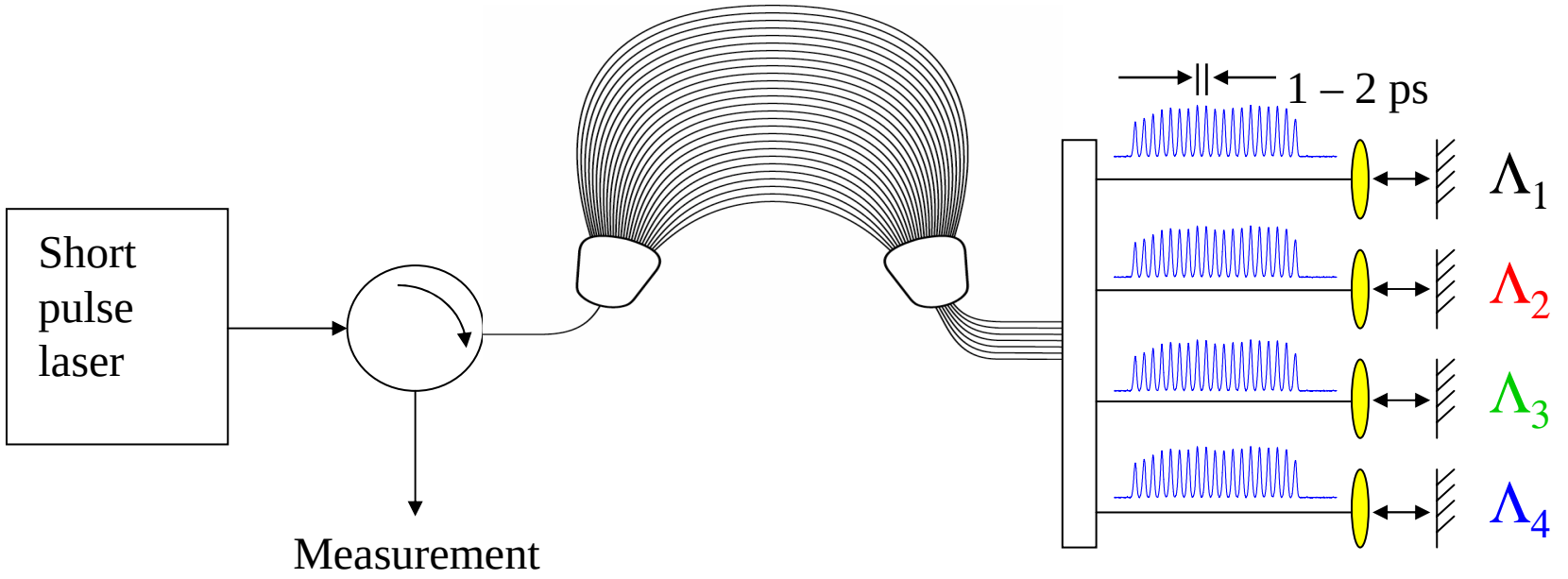
- Arrayed Waveguide Grating (AWG) devices are frequently used in WDM networks as channel multiplexers / demultiplexers.
  - Here we demonstrate novel pulse burst processing enabled by the time-domain response of an AWG.
- We have previously presented a new functionality of AWG devices for generation of time-domain pulse trains (analogous to the DST pulse shaper).
  - 500 GHz to 1 THz burst rep. rate
  - Distinct from AWG spectral slicing
  - Application to rep. rate multiplication
- Double-passing the AWG enables pulse burst generation over an increased temporal window as well as new pulse sequence processing functionalities.

AWG Background

- Commonly used for multiplexing, demultiplexing, and routing in WDM systems
- Femtosecond operation is closely analogous to a DST pulse shaper:
  - Waveguide array acts as combined grating/lens.
  - Output waveguides analogous to multiple output slits.
  - Input slab waveguide and waveguide array apertures provide spatial patterning



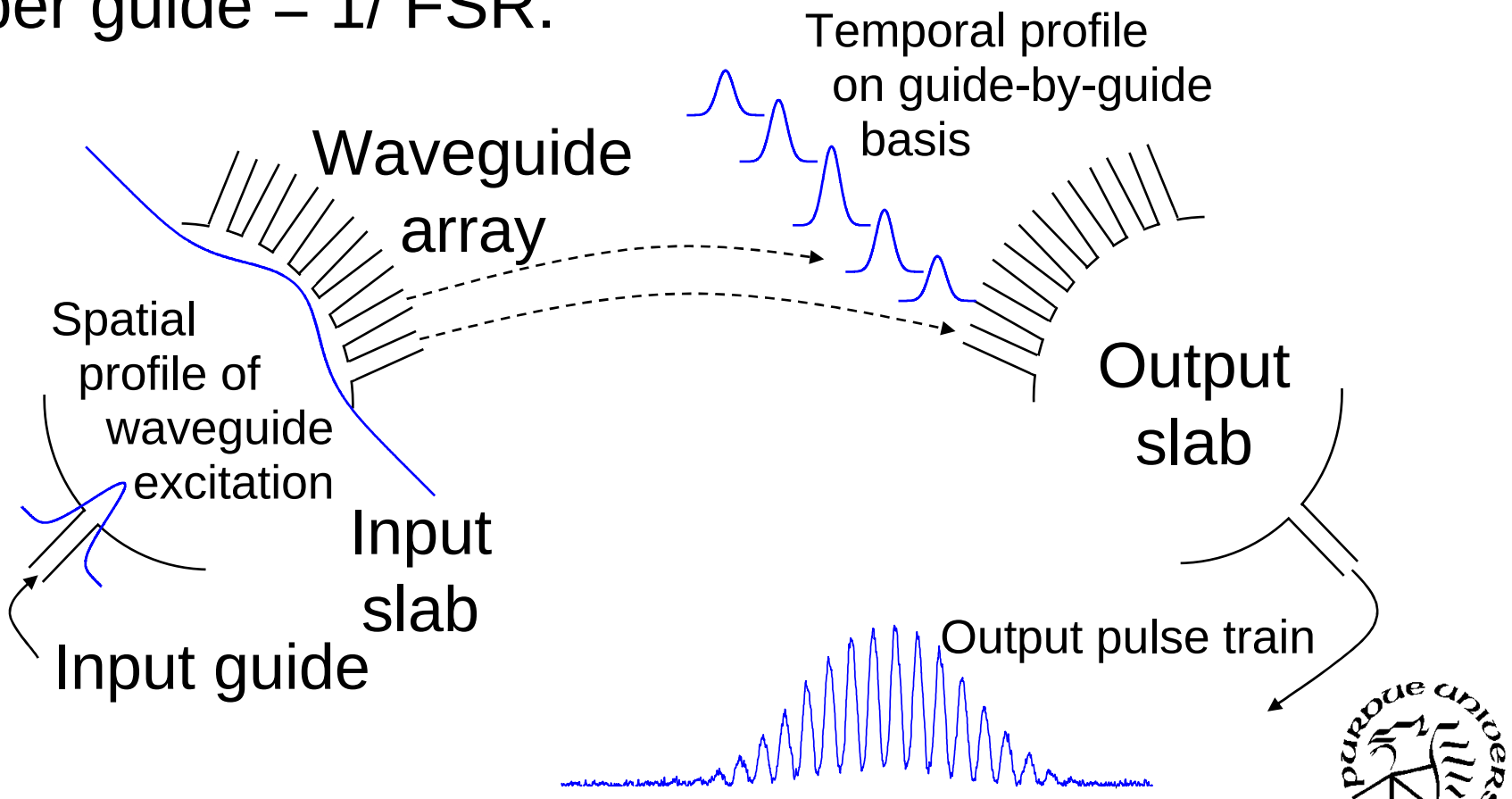
Experimental Apparatus



- Single-pass: 1 pulse in -> high rate pulse burst at each of N output channels.
- Identical, slightly wavelength shifted pulse trains at each channel (1/N energy per output).
- Double-pass allows us to recombine the energy onto a single fiber thereby circumventing power loss.

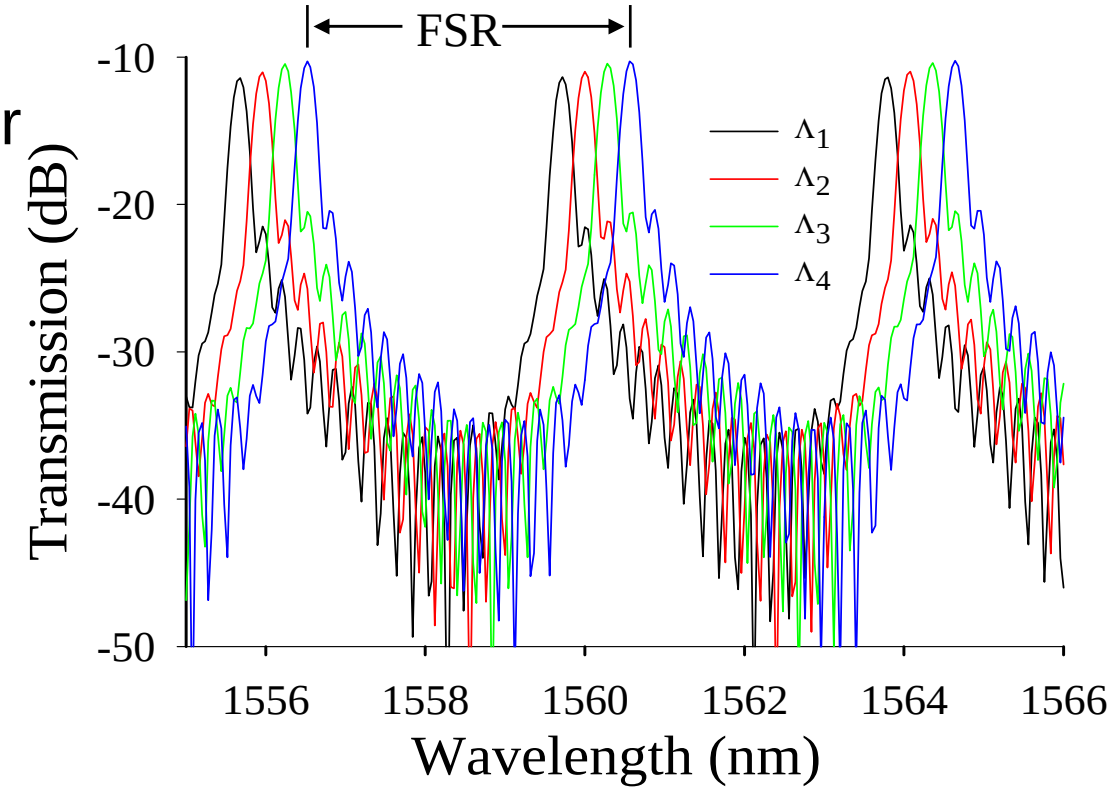
One Guide – One Pulse

- Pulses temporally separated by the delay increment per guide = 1/ FSR.

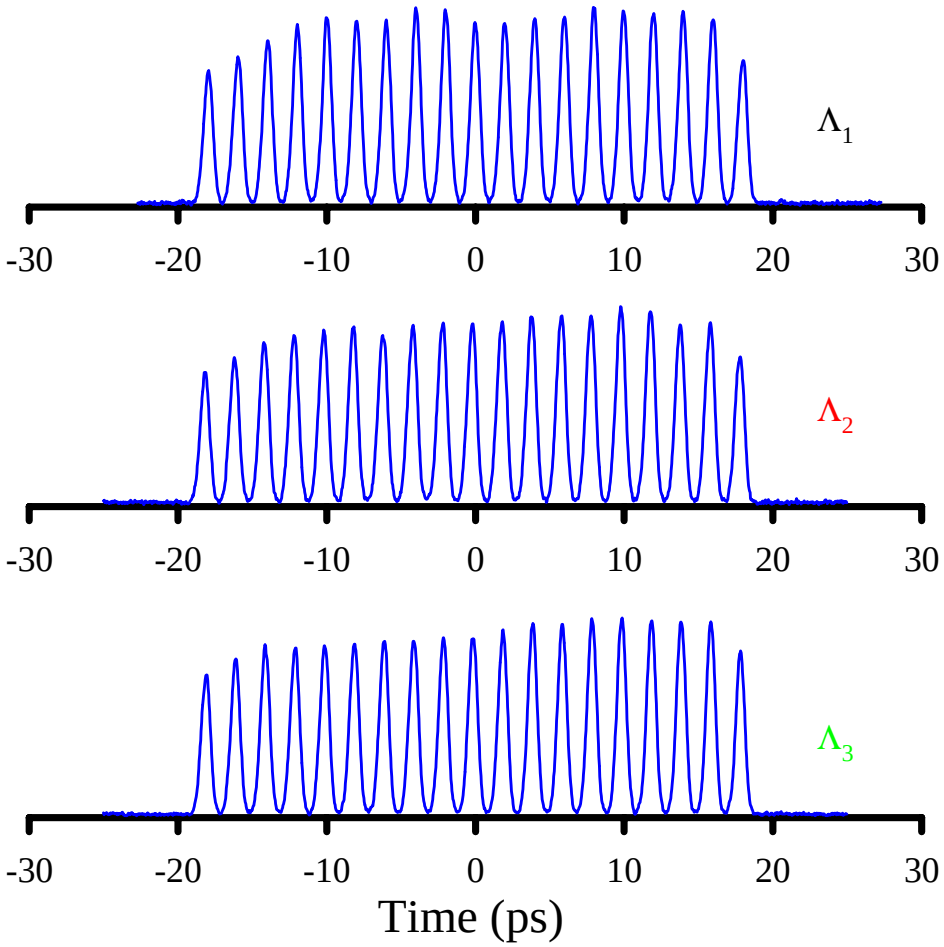


Loss-Engineered AWG's for Flat-top Pulse Train Generation

- Single-pass power spectra.
- Multiply peaked power spectrum - 500 GHz FSR.
- Output channel spacing 40 GHz.
- Sinc-like character due to loss-engineering to produce flat-topped temporal intensity profile in single-pass.



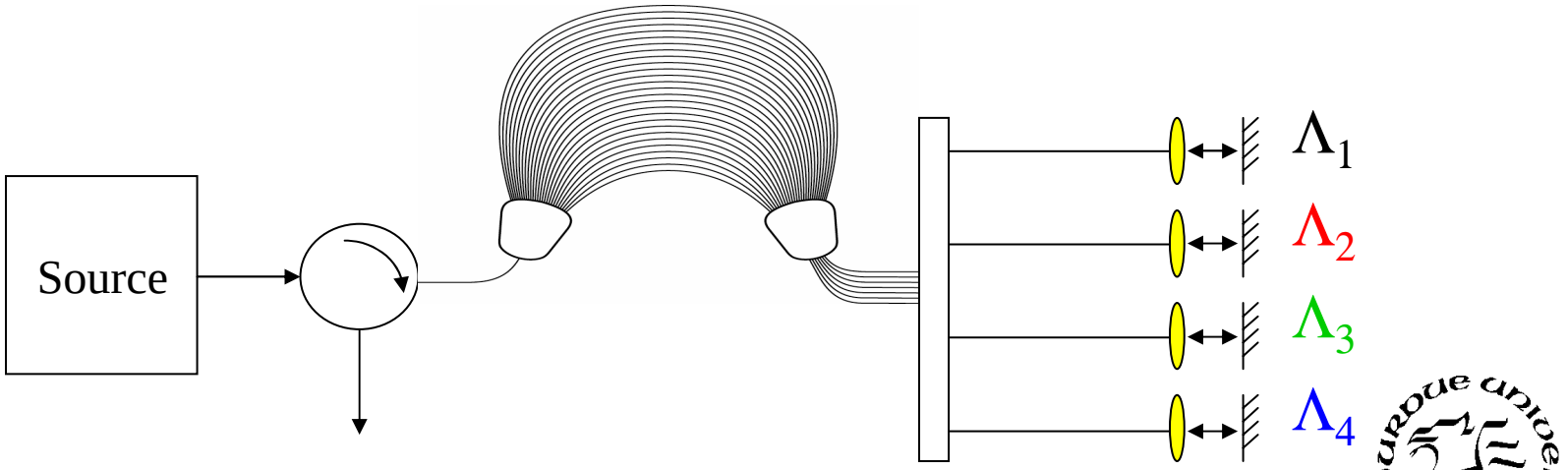
Single-Pass Temporal Response



- Temporal intensity profile is unchanged across the output fibers.
- 2 ps pulse spacing = 1 / FSR.

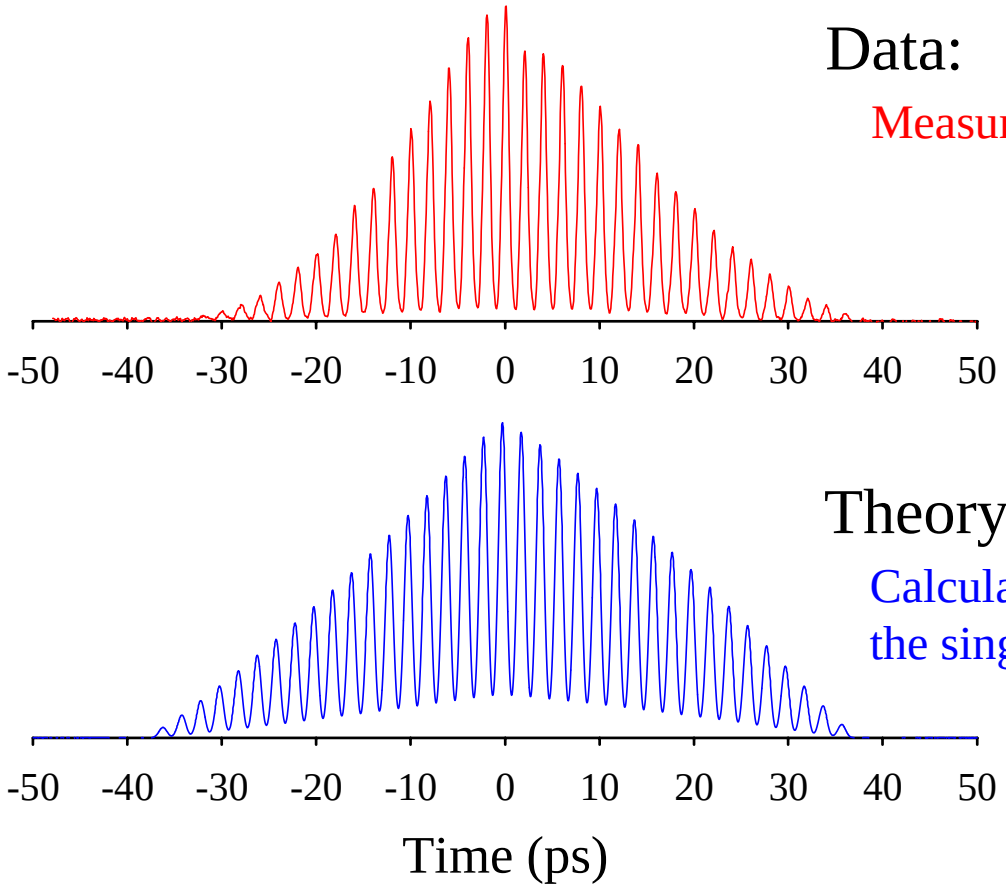
Consider One Single-Pass 'Output'

- Each pulse in the burst produced in the first pass of the AWG will generate another burst upon double-pass.
- The pulses add upon double-pass.
- Double-pass temporal response is the convolution of the single-pass response.



Double-Pass Temporal Response – Single Channel

Square pulse burst in single-pass converted to triangle in 2-pass



Data:

Measured X-correlation

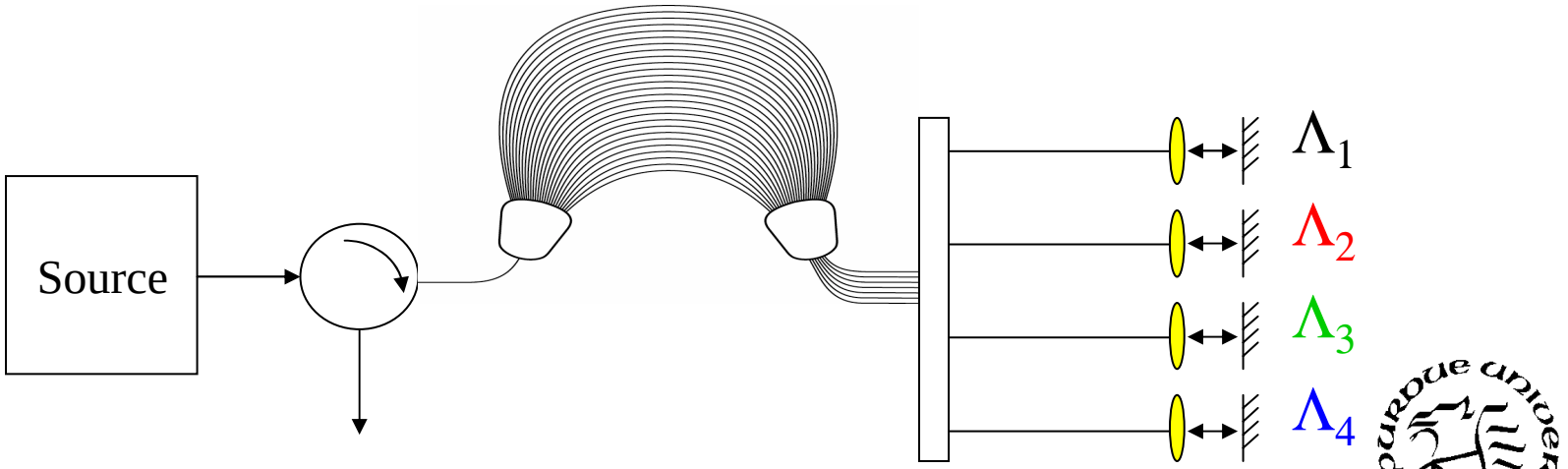
2-pass pulse shape in good agreement with theory

Theory:

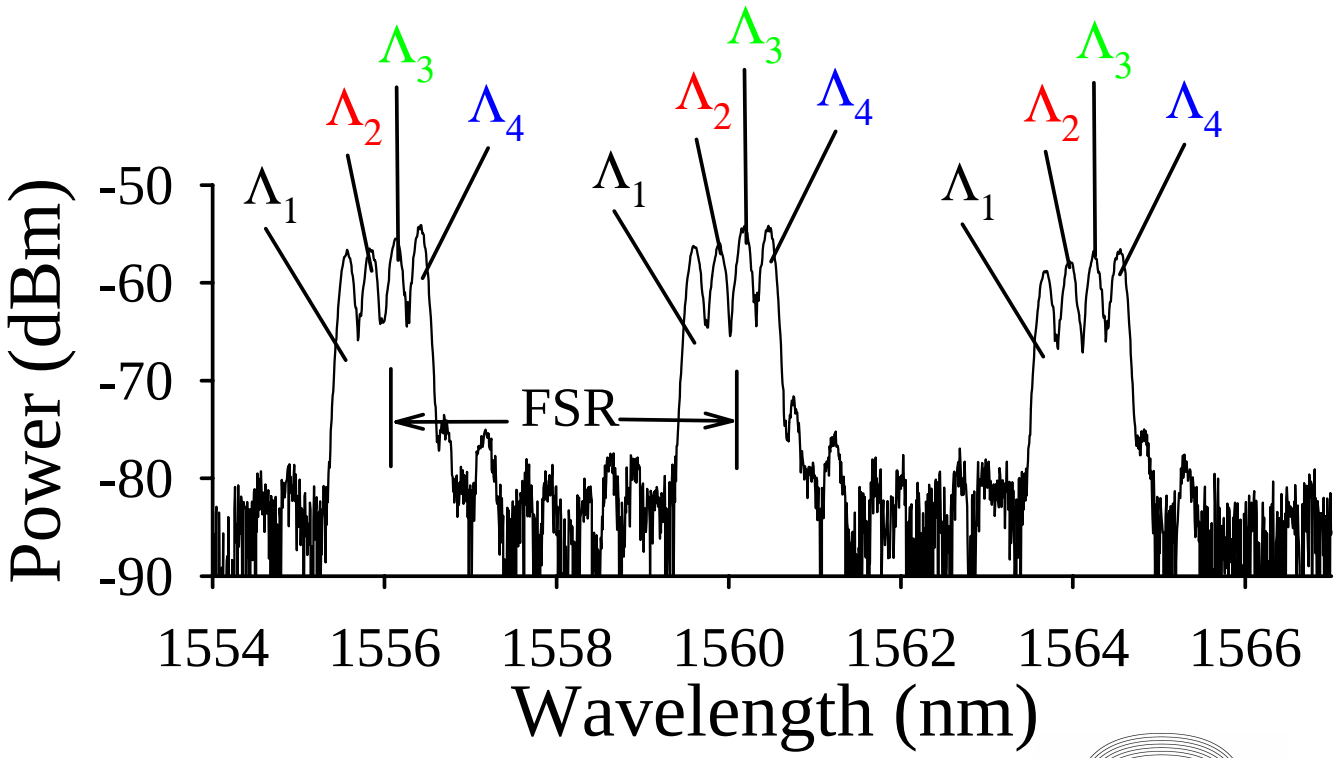
Calculated by auto-convolving the single-pass temporal response

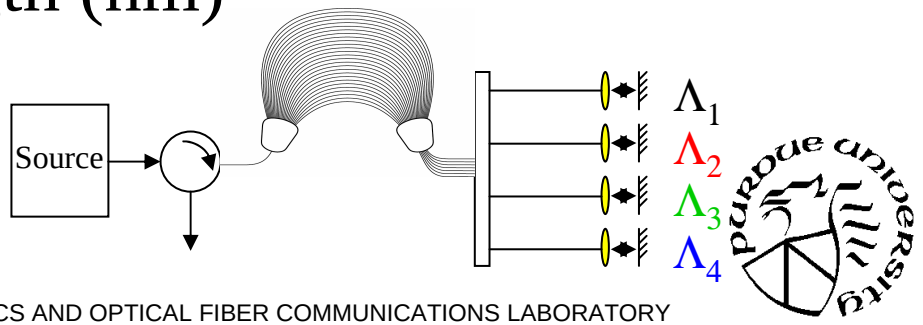
Multiple Single-Pass ‘Outputs’

- Frequency ‘comb’ associated with each single-pass ‘output’ will be recombined onto one channel.
- Temporally, the pulse bursts associated with each single-pass ‘output’ will be recombined with a delay determined by the free-space coupling.

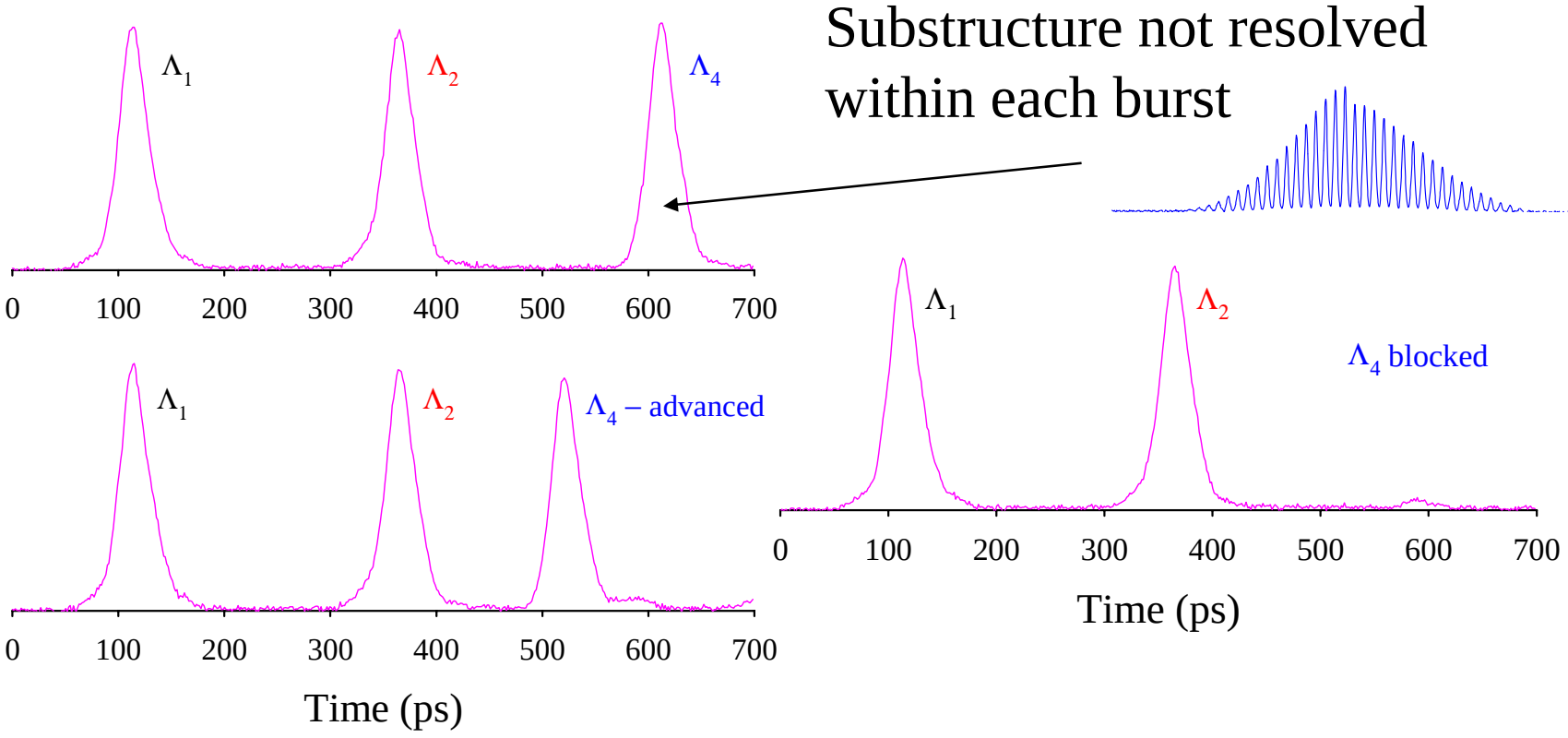


Multiple Free-Space Sections





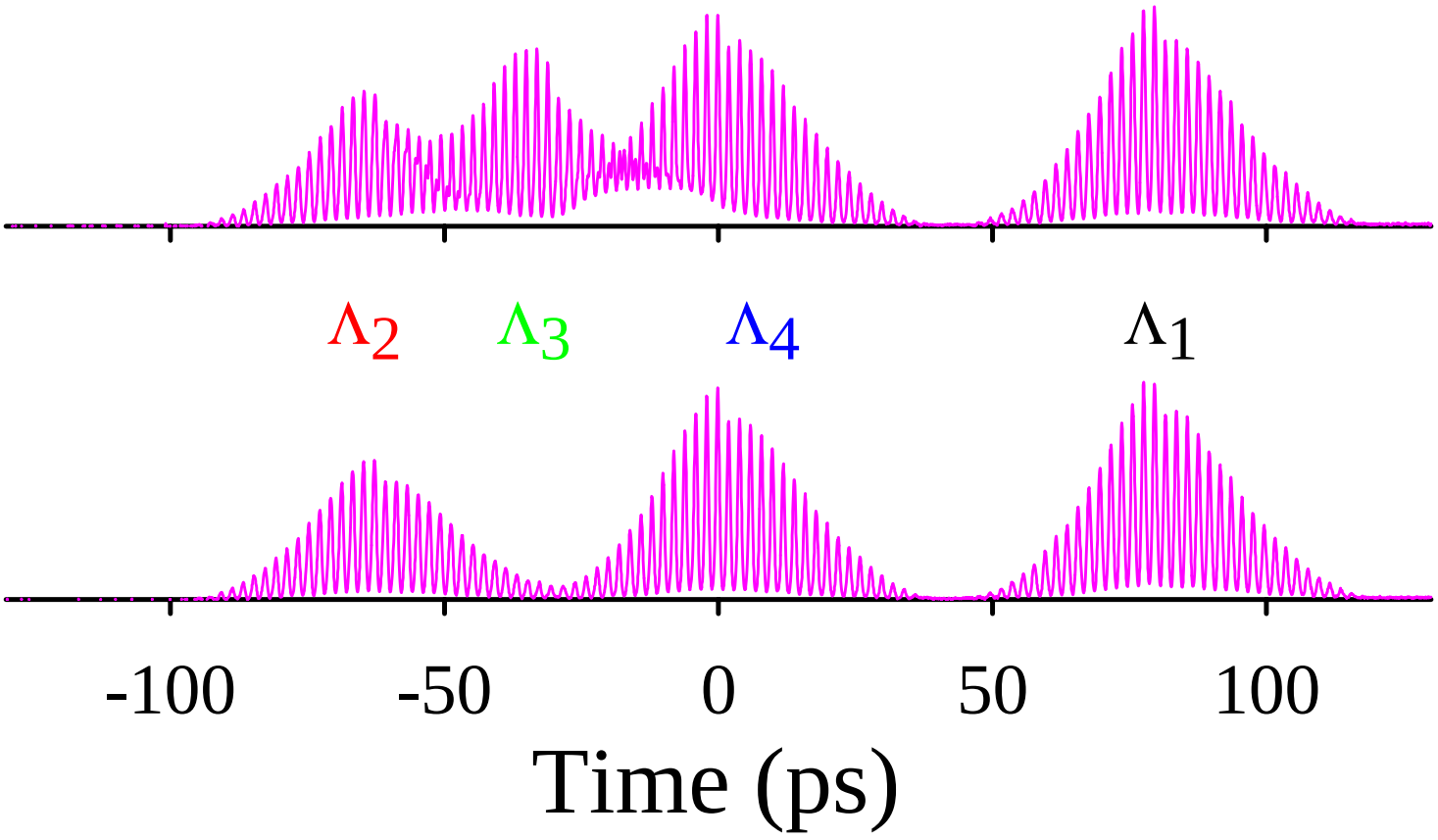
Multiple Channel Temporal Response



- Pulse bursts observed with a 50 GHz photodiode and sampling scope. Delay between bursts controlled by adjusting the single-pass 'output' free-space sections.

Pulse Burst Processing

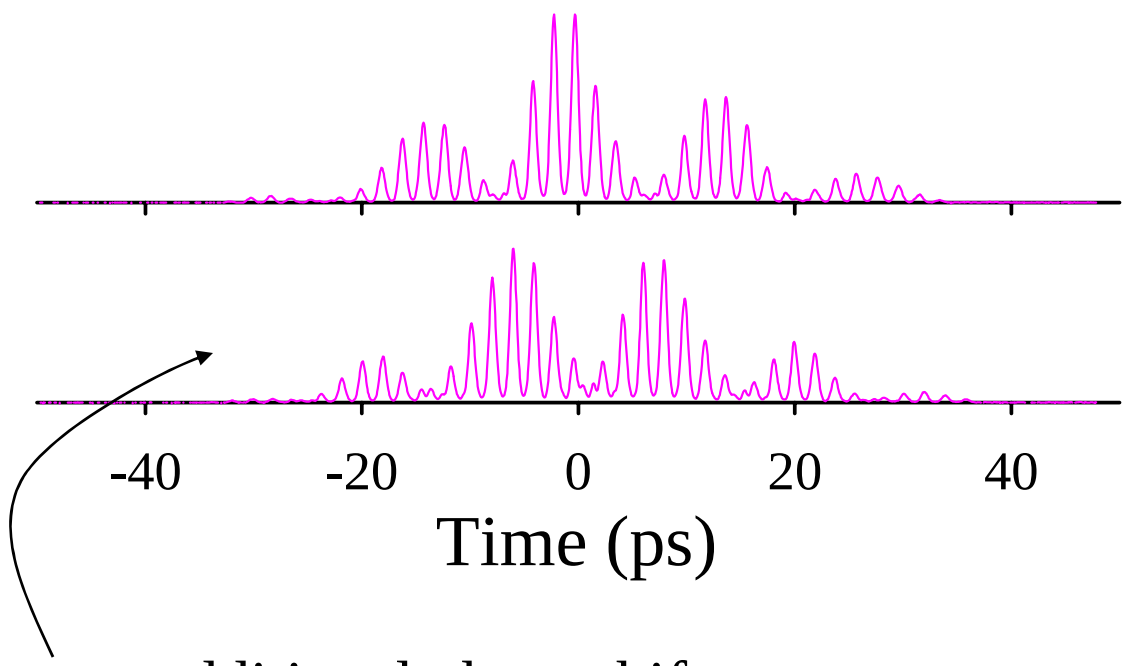
Multiple wavelengths nonoverlapped in time and noninterfering



Cross correlation to fully resolve all temporal features

Temporally Overlapped Free-Space Sections

Two wavelength channels overlapped in time and interfere



- Free-space sections separated by 80 GHz overlapped with ~0 delay.
- Bursts interfere at a 12.5 ps period.

Conclusion

- Very-high repetition rate pulse bursts (500 GHz demonstrated here) can be generated with an increased number of pulses by double-passing an AWG.
  - FSR < bandwidth of the input pulse is a design constraint.
  - Equivalently, two identical AWG's connected back-to-back provides the same functionality in transmission.
- With further engineering of the AWG, application to repetition-rate multiplication of a lower-rate source may be possible.
  - Future: 1 pulse split into 100's of pulses.