Distortion-Reduced Pulse-Train Propagation with Large Delay in a Triple Gain Media

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Outline

- Motivation
- Principles
- Experimental Setup
- Results and Analysis
- Summary

Motivation

- Slow Light for telecommunication
  - Optical delay-line / buffer
  - Data re-synchronization
  - Jitter correction
- Slow Light based on Stimulated Brillouin Scattering (SBS) effect [1, 2]
  - Wide wavelength range
  - Good dynamic controllability
  - Con: limited by bandwidth and distortion

1. Y. Okawachi, *et al.* Phys. Rev. Lett. 94, 153902 (2005)
2. K. Y. Song, *et al.* Opt. Express 13, 82–88 (2005)

Principles: single gain line

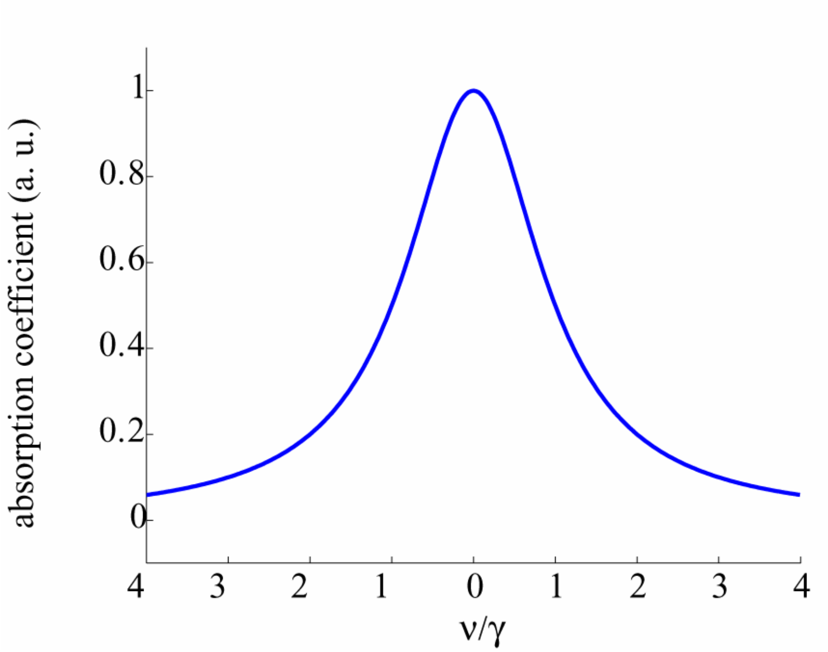
ν -- detuning from the line center

g_0 -- amplitude gain coefficient

γ -- Brillouin gain linewidth

$$\tilde{n}(\nu) = 1 + \frac{g_0\gamma}{2k_0}\frac{1}{\nu + i\gamma}$$

Gain coefficient



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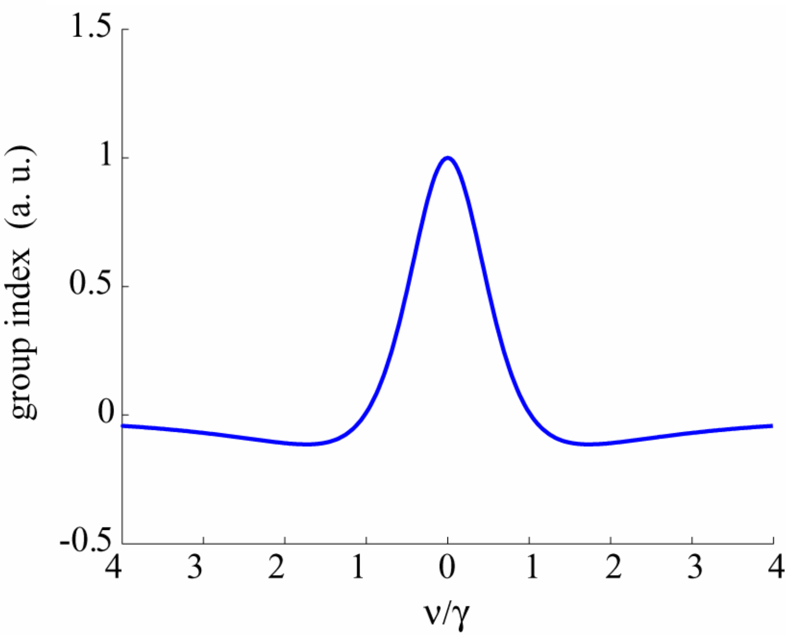
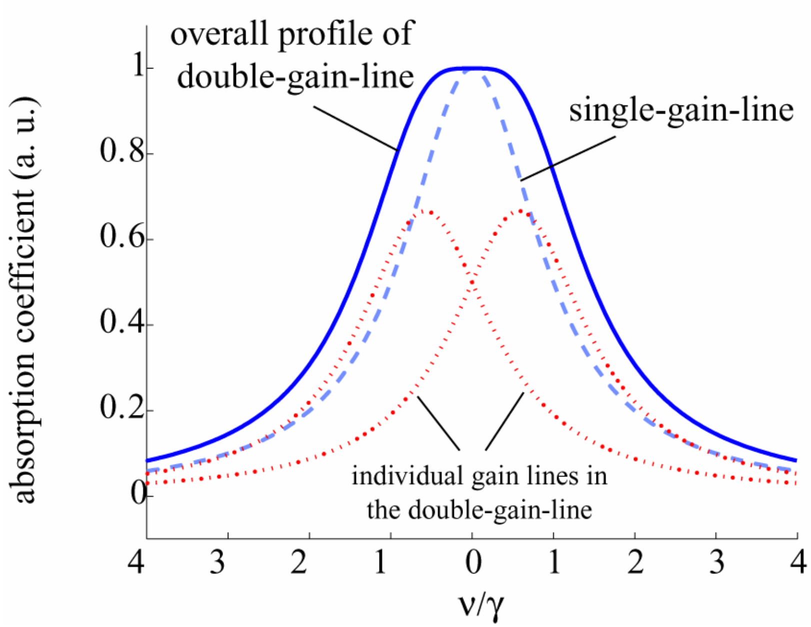


Principles: double gain line

$$\tilde{n}(\nu) = 1 + \frac{g_0\gamma}{2k_0}\left\{\frac{1}{(\nu-\delta)+i\gamma} + \frac{1}{(\nu+\delta)+i\gamma}\right\}$$

Gain coefficient



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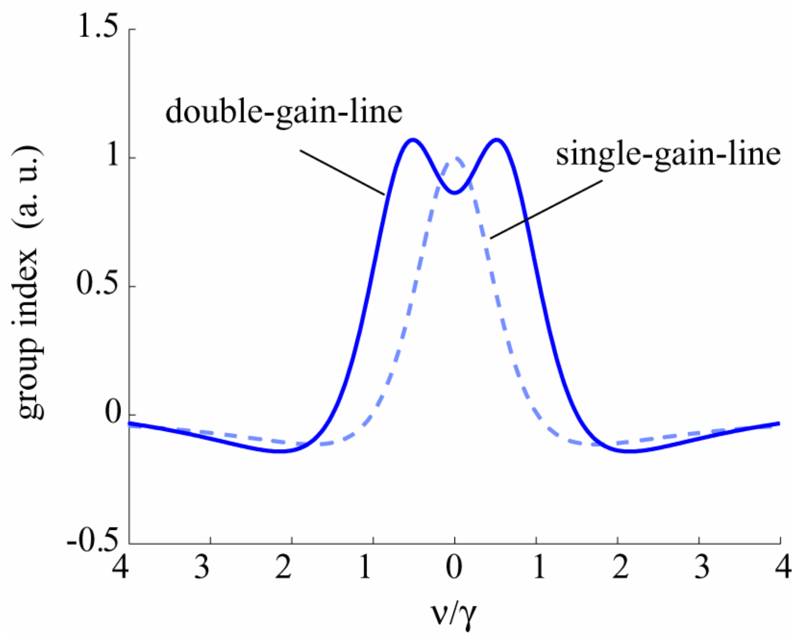
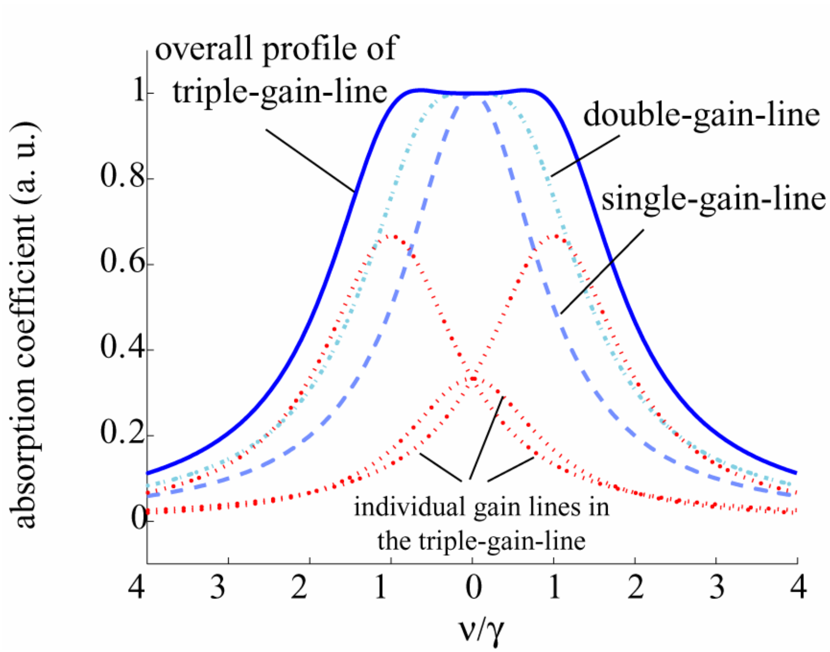


M. Stenner, *et al.* Opt. Express 13, 9995-10002 (2005)

Principles: triple gain line

$$\tilde{n}(\nu) = 1 + \frac{g_0\gamma}{2k_0}\left\{\frac{1}{(\nu-\delta)+i\gamma} + \frac{1}{(\nu+\delta)+i\gamma} + \frac{r}{\nu+i\gamma}\right\}$$

Gain coefficient



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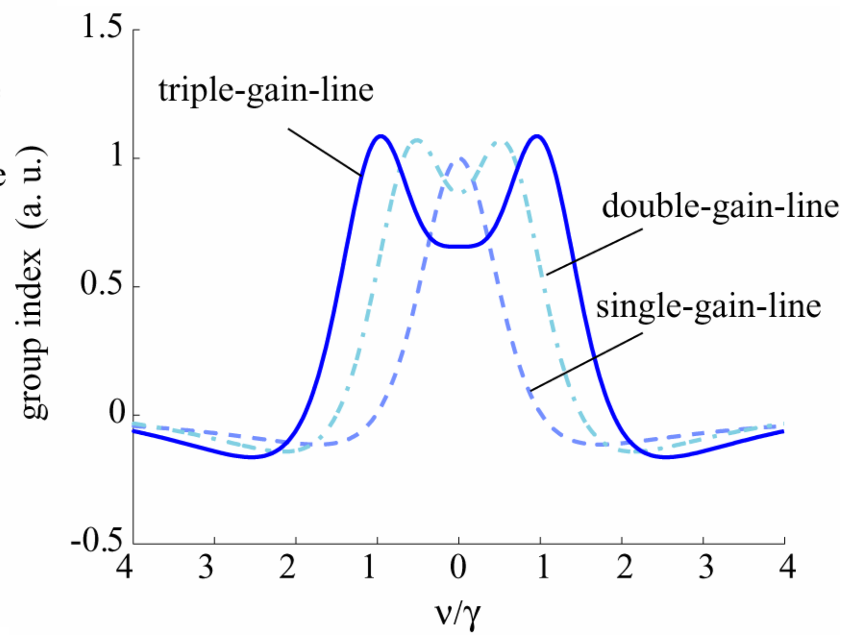
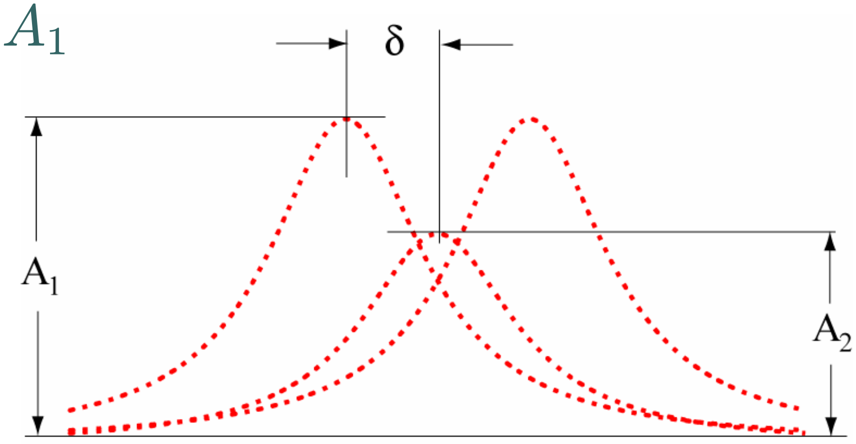


Principles: triple gain line

- Free parameters for a triple-gain-line medium:
  - half-separation δ
  - Side line gain peak A_1
  - Peak ratio

$$r = \frac{A_2}{A_1}$$



Principles: triple gain line

- Gain line separation and peak ratio are optimized for each bandwidth using the following 3 criteria
  - Maximal amplitude gain

    $$G_{\max} < 3.5$$

  - Phase distortion factor

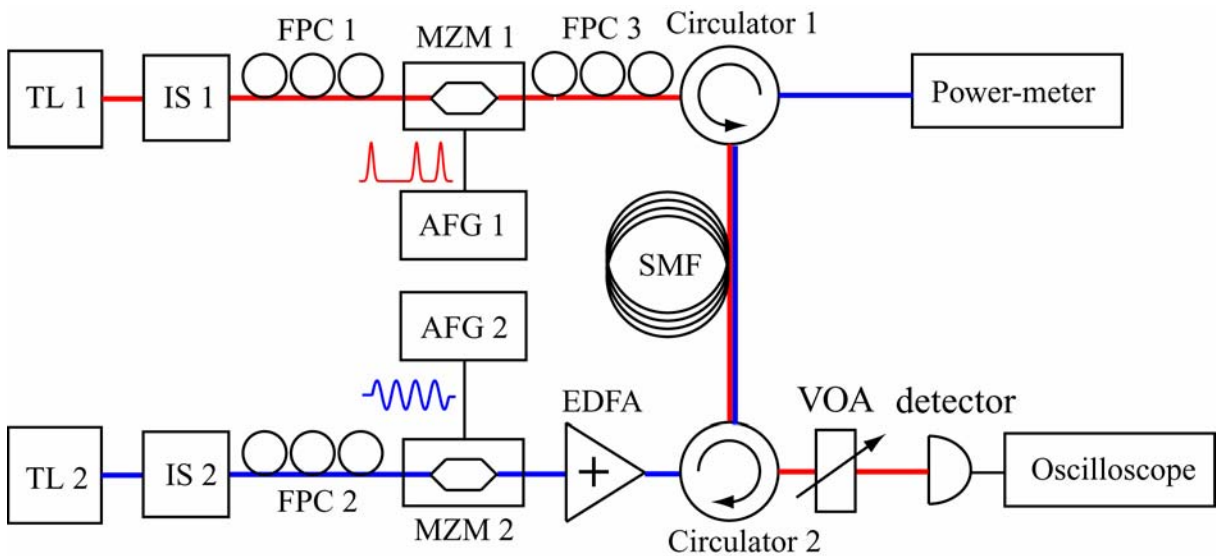
    $$D_p \equiv (\max\{n_{\text{dev}}\} - \min\{n_{\text{dev}}\}) k_0 L / 2\pi < 0.05$$

    $$n_{\text{dev}} \equiv n(\nu) - n^{(0)} - \nu n^{(1)}$$

  - Gain distortion factor

    $$D_g \equiv (G_{\max} - G_{\min}) \, / \, (G_{\max} + G_{\min}) < 0.05$$

Experimental Setup

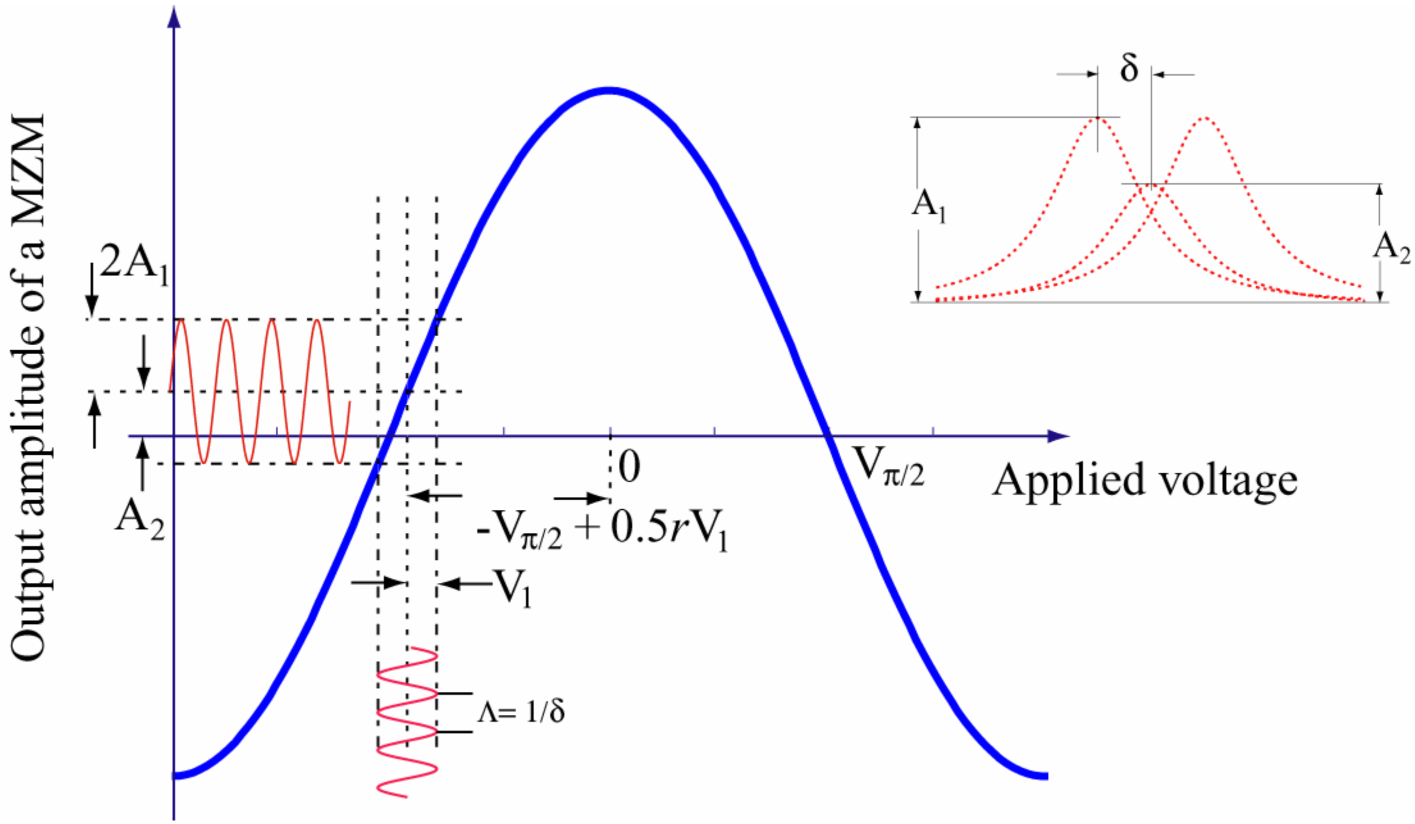


Schematic diagram for the multi-gain-line SBS experiment

TL: tunable laser; ***IS***: isolator; ***FPC***: fiber polarization controller; ***MZM***: Mach-Zehnder modulator; ***AFG***: arbitrary function generator; ***SMF***: single mode fiber; ***VOA***: variable optical attenuator.

Pump amplitude modulation

$$E_{out,pump} = E_0 \cos \alpha(-V_{\frac{\pi}{2}} + \frac{r}{2}V_1 + V_1 \cos 2\pi\delta t)$$

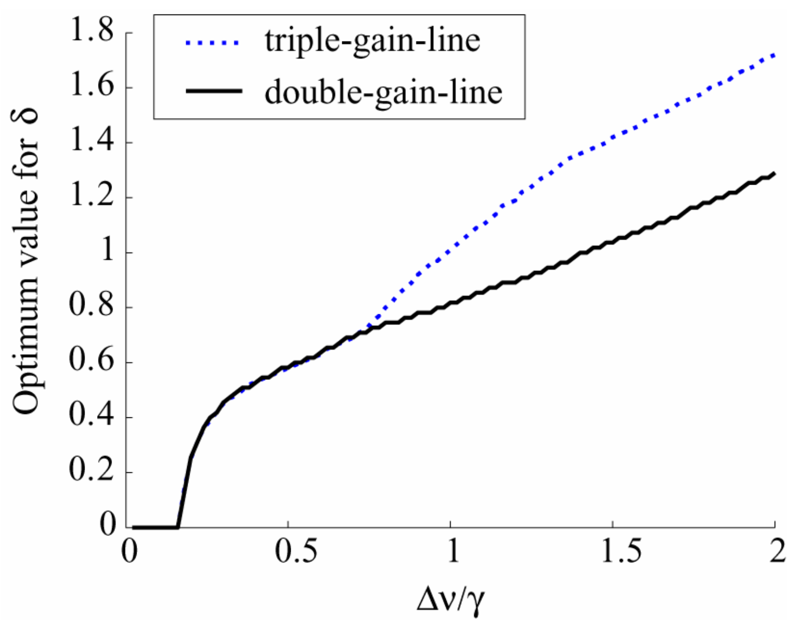


Experimental Setup

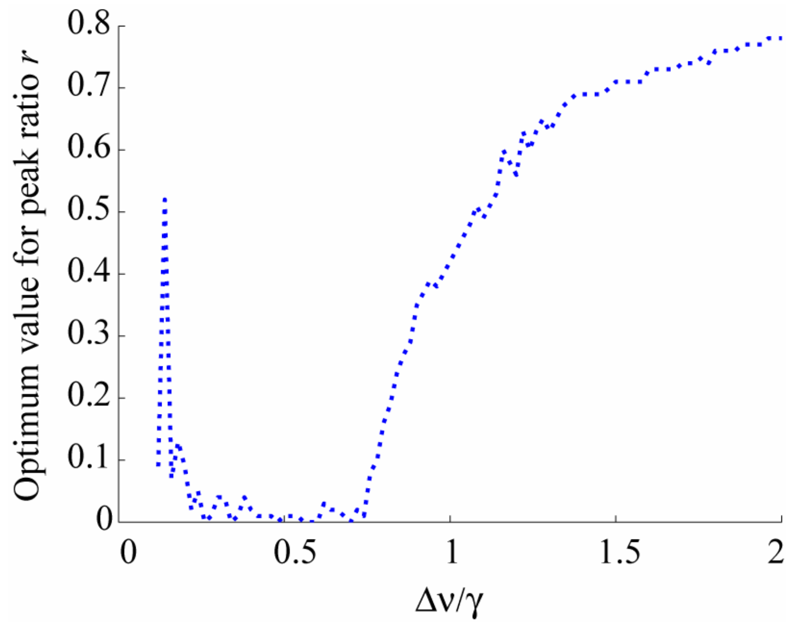
- SBS Gain is controlled by changing the gain of the EDFA
- Delay is measured by comparing signal output with/without pump

Results : Optimum configuration

Half separation

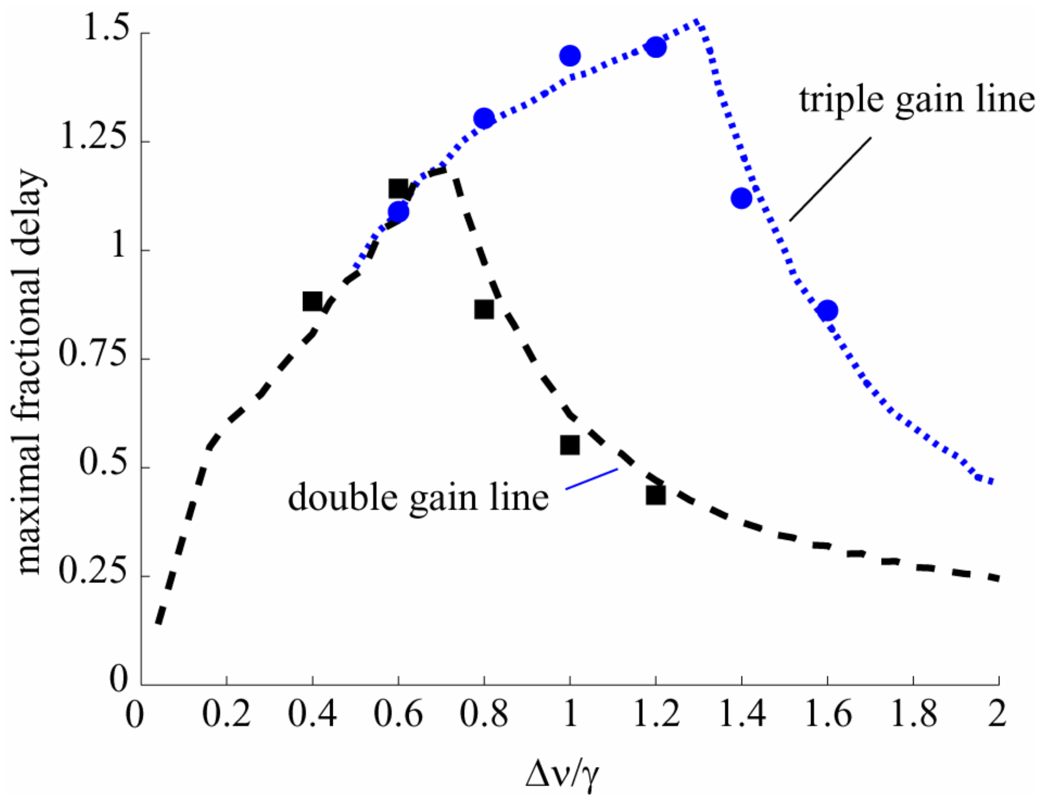


Peak ratio

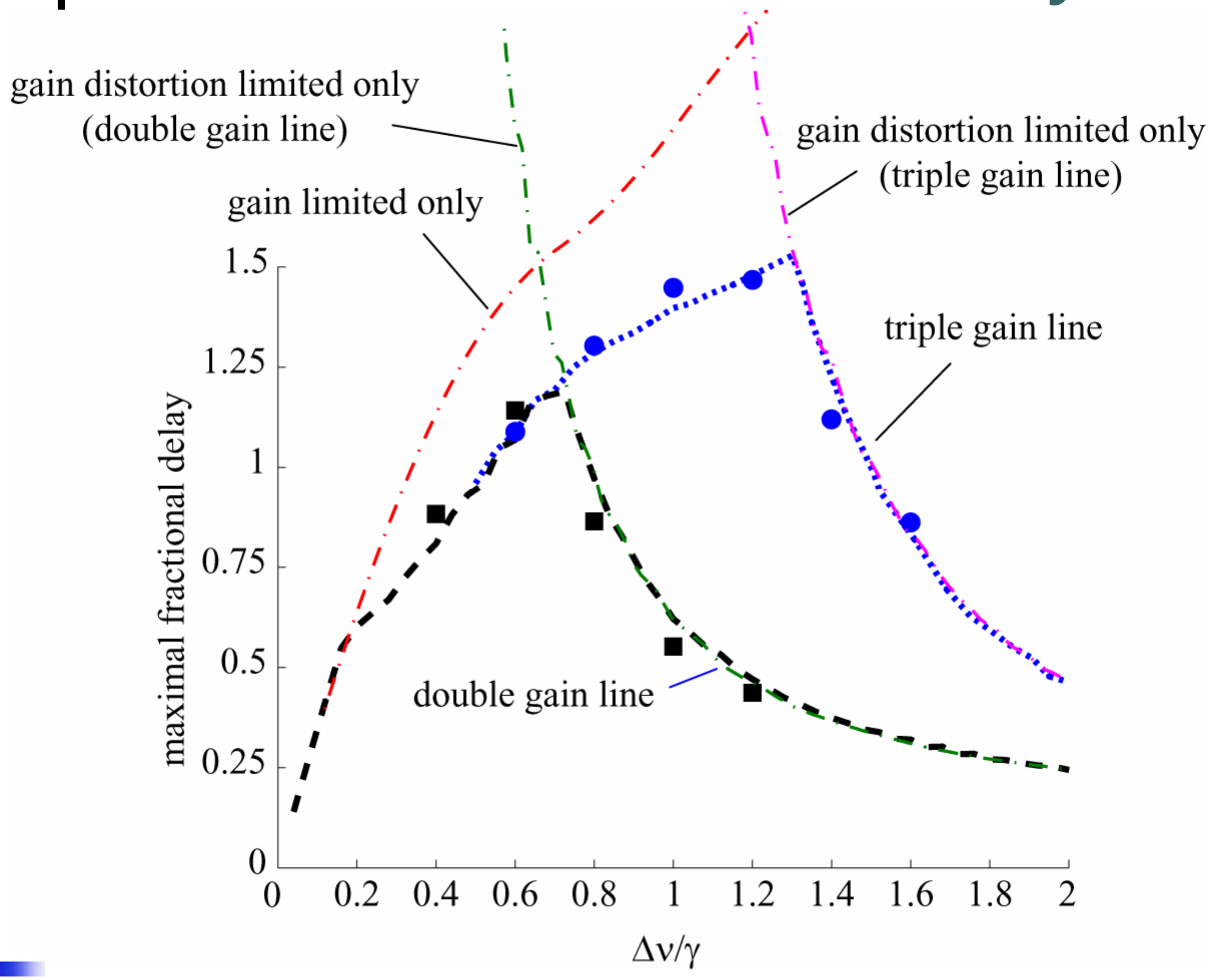


Results: Maximum delay

$$FD \equiv \Delta T 2\pi \Delta\nu$$

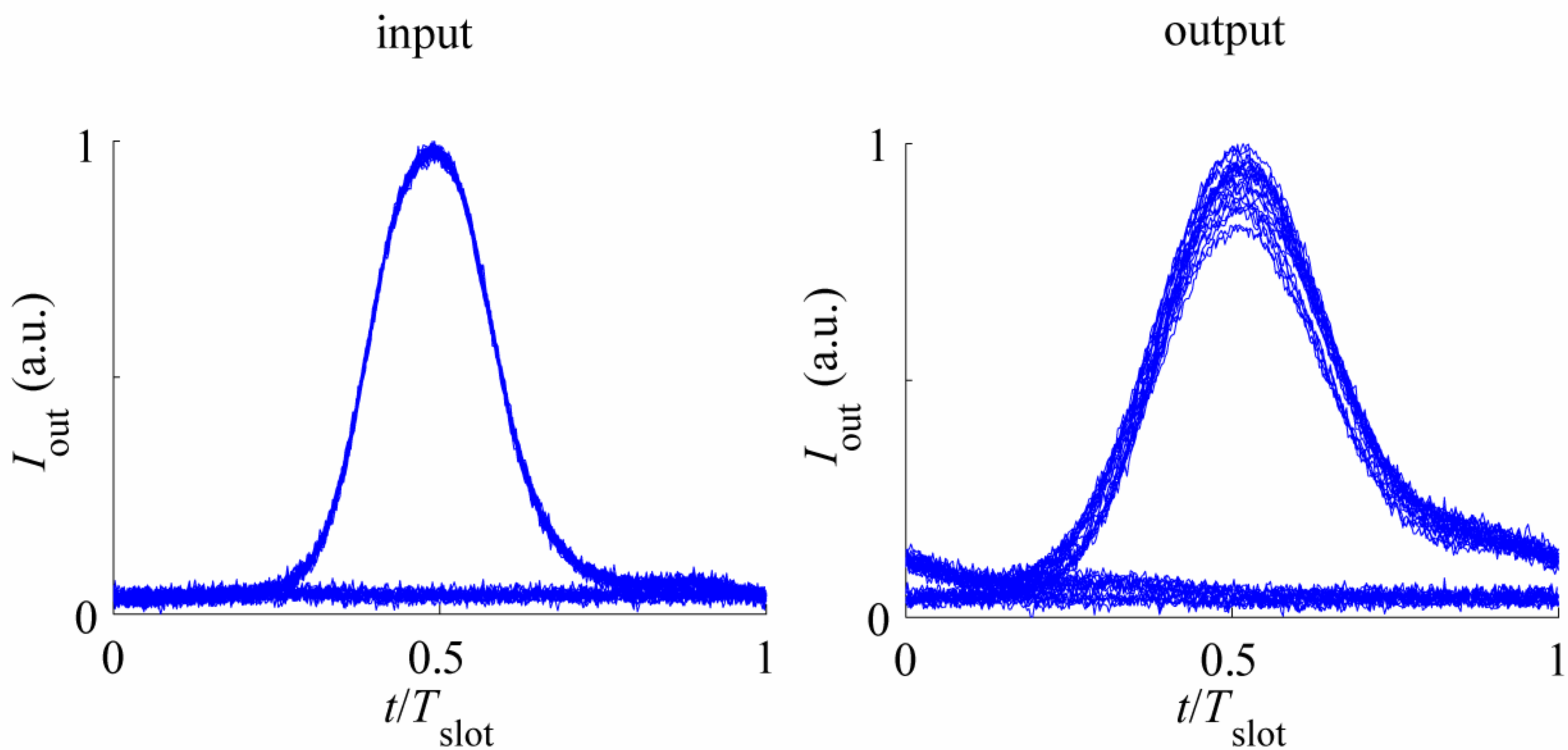


Results: Maximum delay



Results: Eye-diagram

$\Delta\nu = 1.6\gamma$



Summary

- Multiple gain lines can be produced by biased amplitude modulation on the pump field in a SBS slow light system.
- Using a triple-gain-line system, fractional delays up to 1.5 (>30% improvement than a double-gain-line system) can be achieved with very small distortion.
- In this demonstration, γ = 23.5 MHz. However, it has been shown that γ can be increased up to 12 GHz using a spectrally broadened pump[1].

Z. Zhu, *et al.* J. Lightwave Technol. (submitted)

Acknowledgement

Thank you for your attention!