Transient Gain Dynamics in Saturated Raman Amplifiers with Multiple Counter-propagating Pumps

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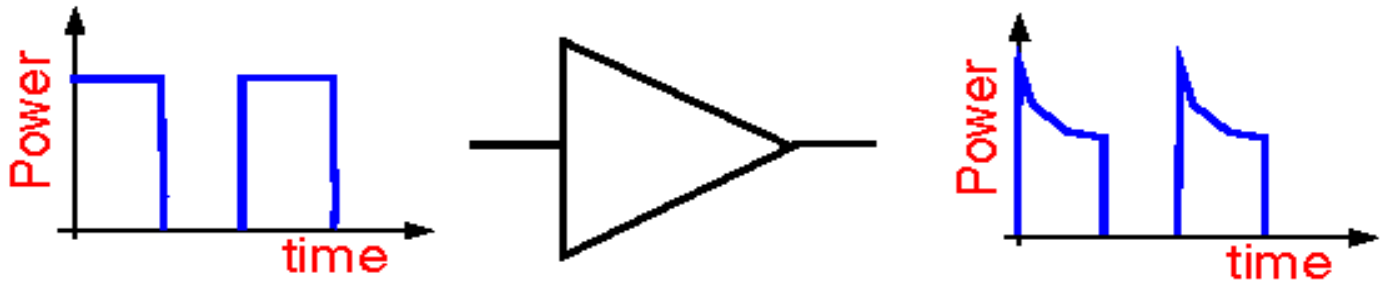
Outline

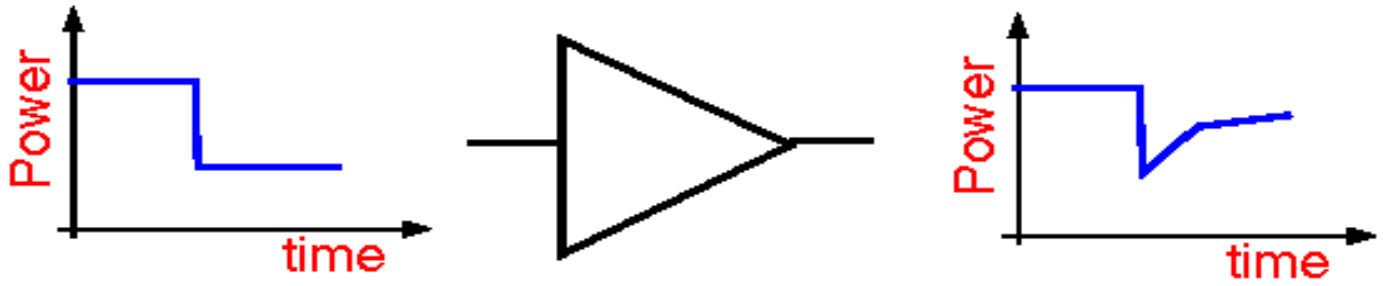
- Motivation
- Amplifier block diagrams
- Model assumptions and limitations
- Examples
- Conclusions

MOTIVATION

Burst-Mode Packet Transmission



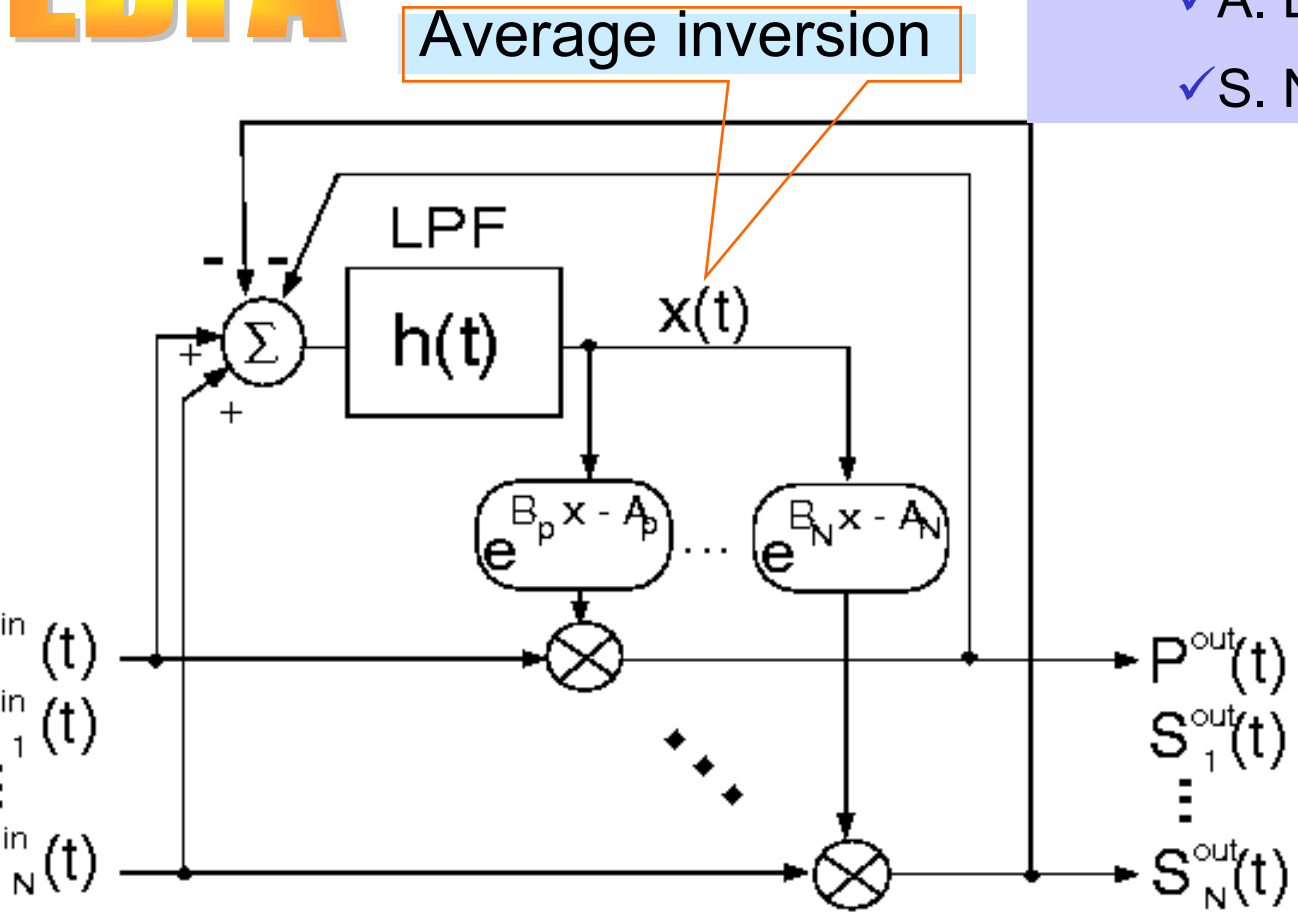
Channel Add/Drop



AMPLIFIER BLOCK DIAGRAMS

EDFA

- ✓Y. Sun *et al.* JSAQE Aug 97
- ✓A. Bononi *et al.* JLT May 98
- ✓S. Novak *et al.* JLT June 02



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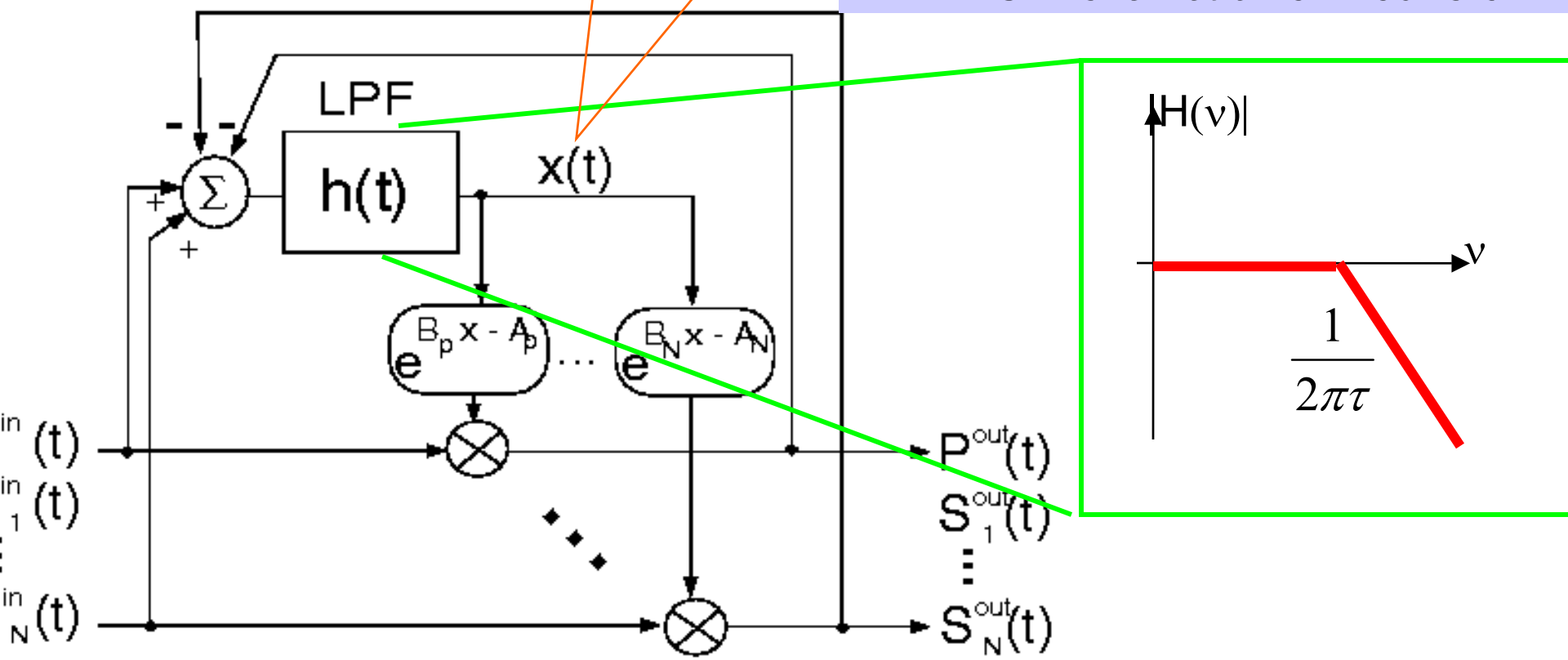
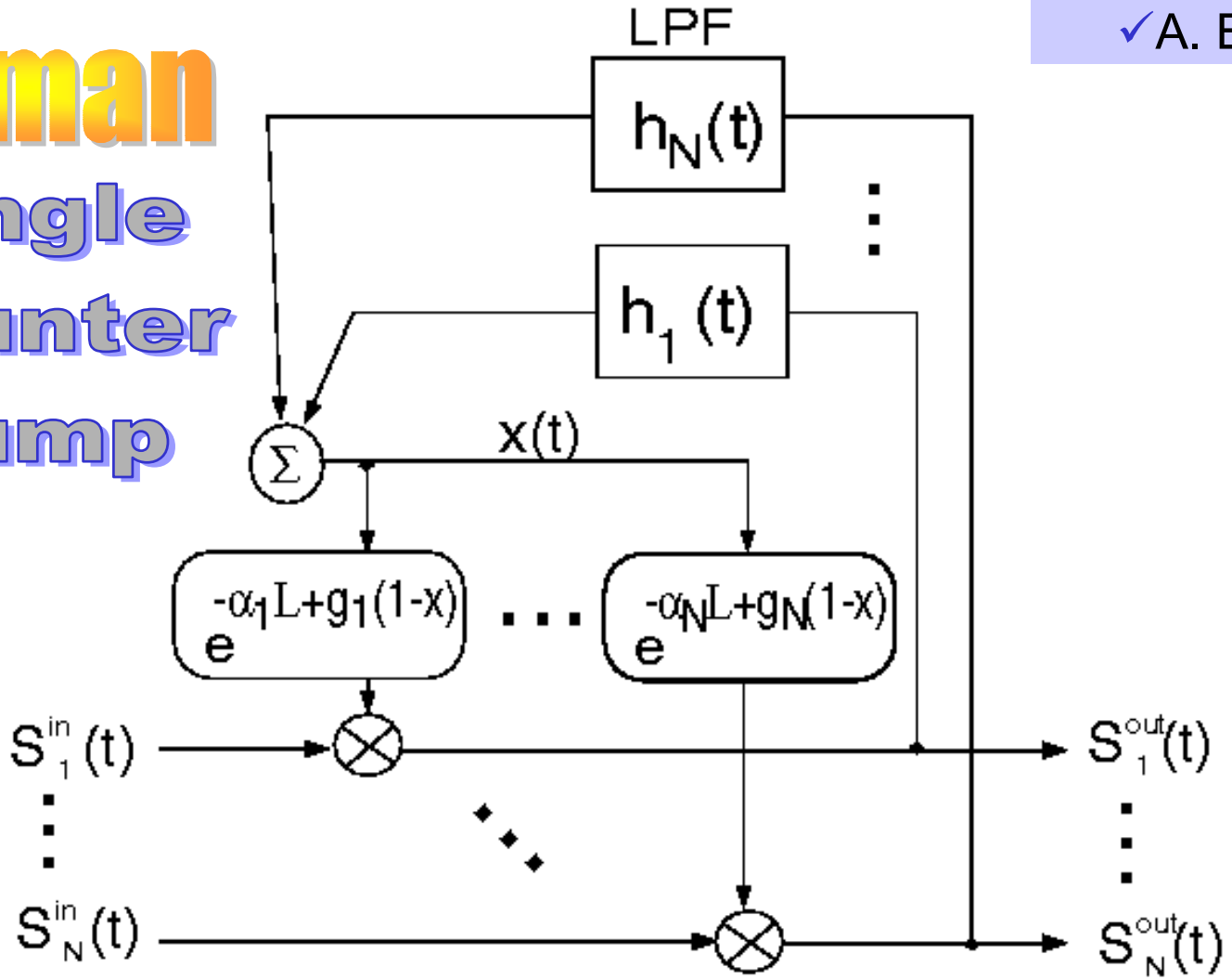


AMPLIFIER BLOCK DIAGRAMS

Raman
single
counter
pump



✓A. Bononi *et al.* OFC 02

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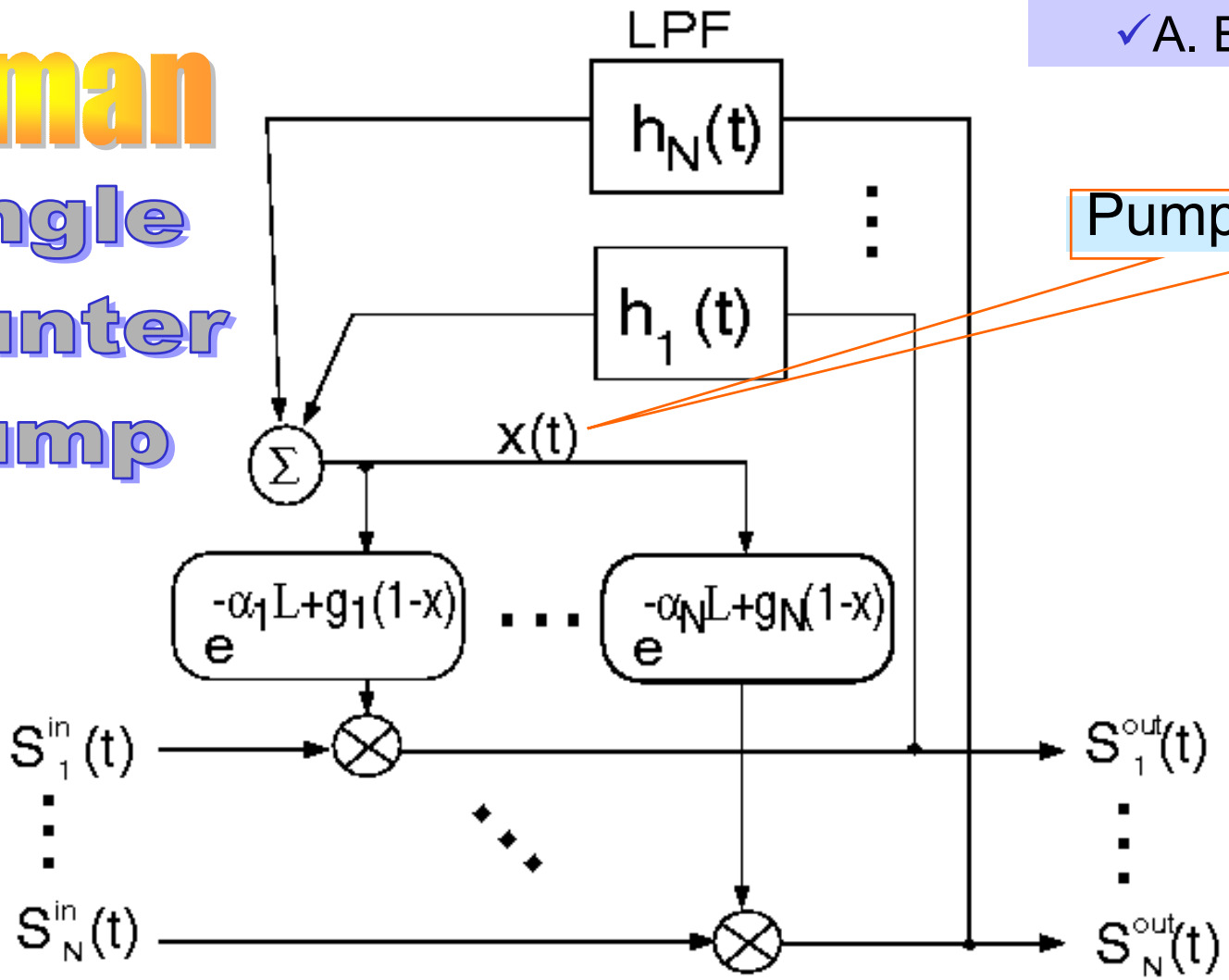

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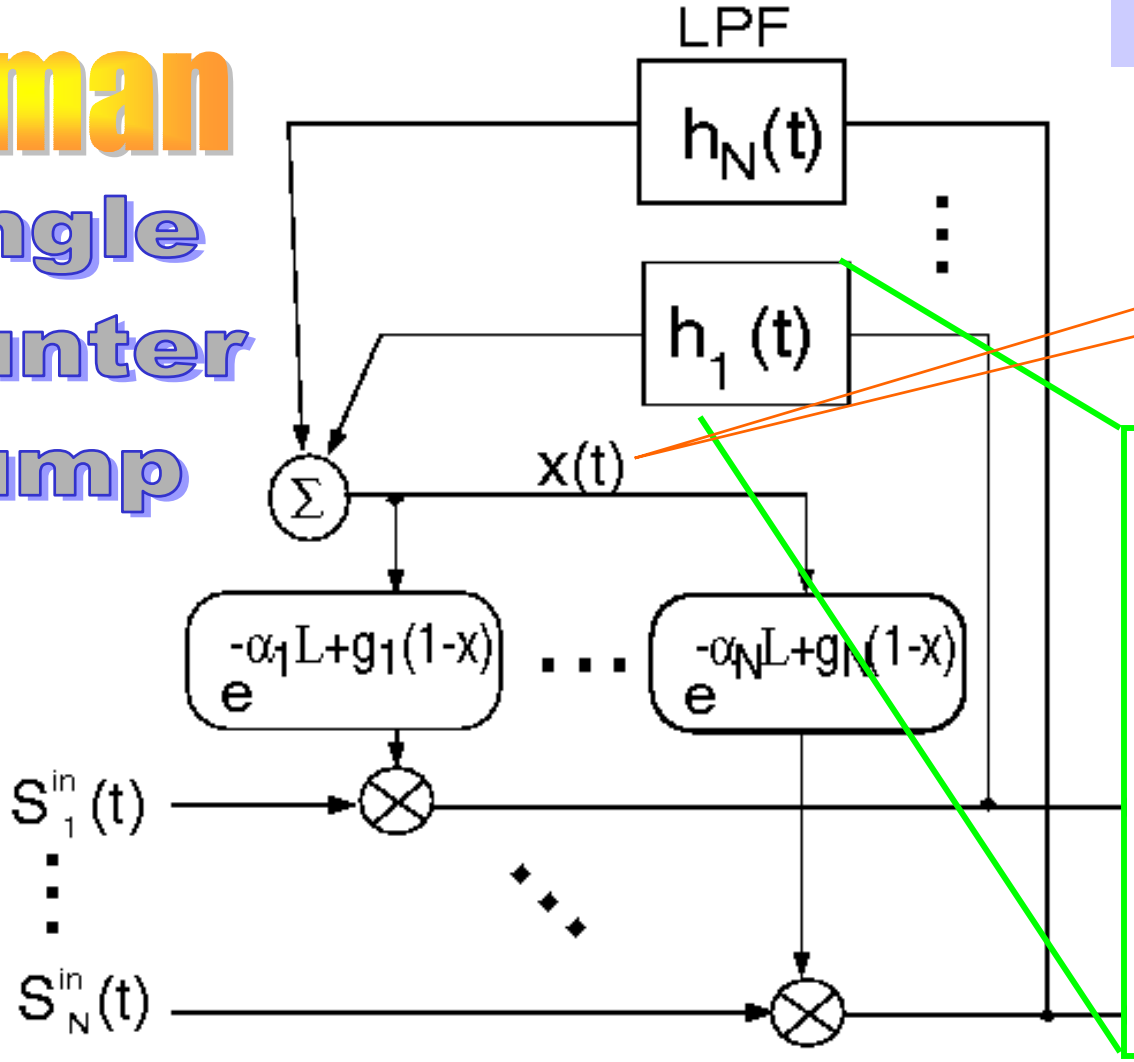
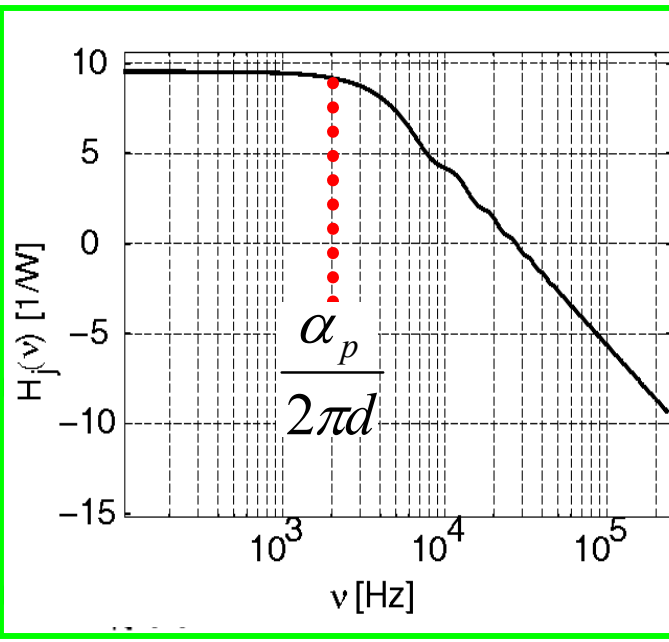


✓A. Bononi *et al.* OFC 02

Pump depletion %



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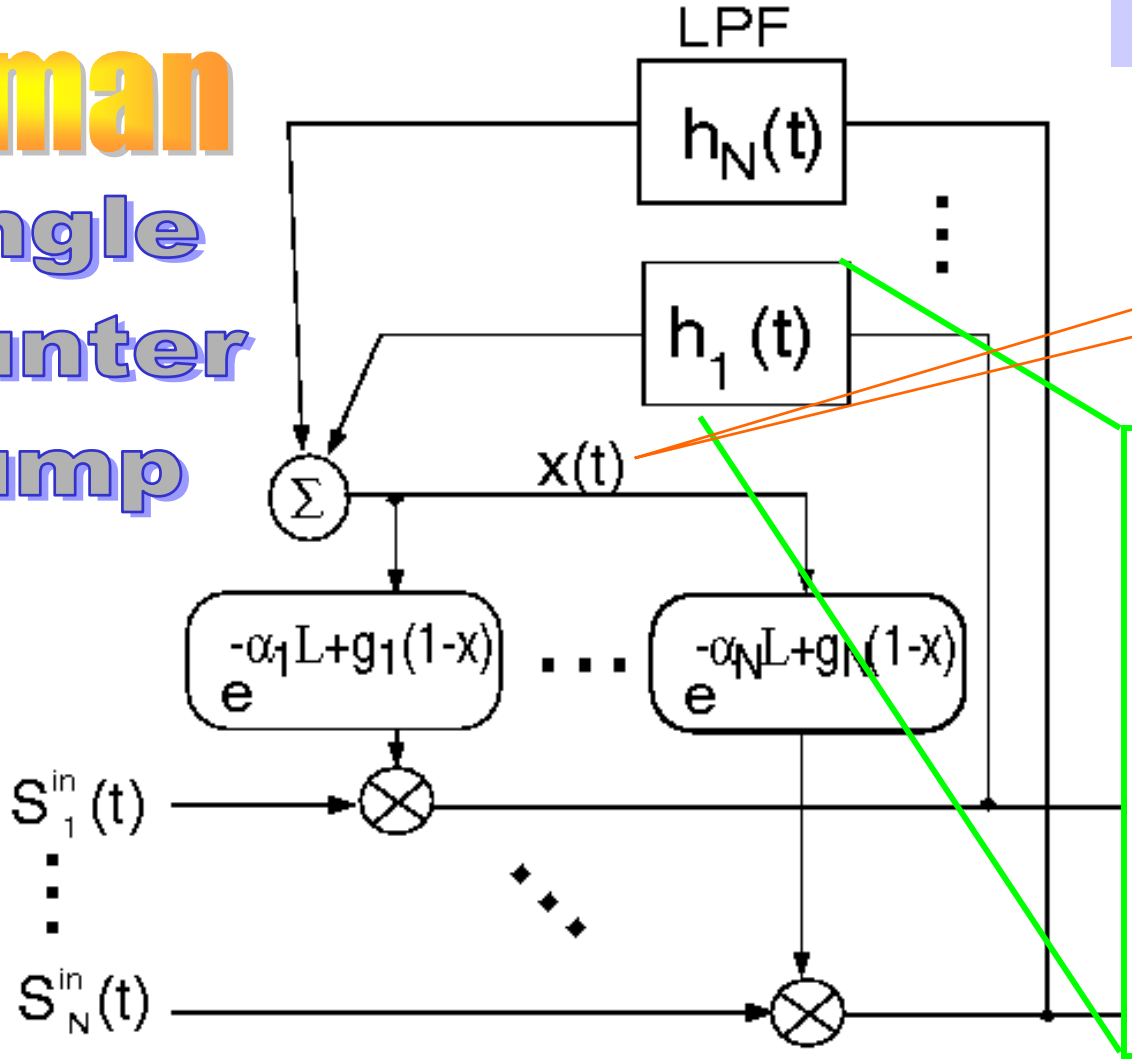
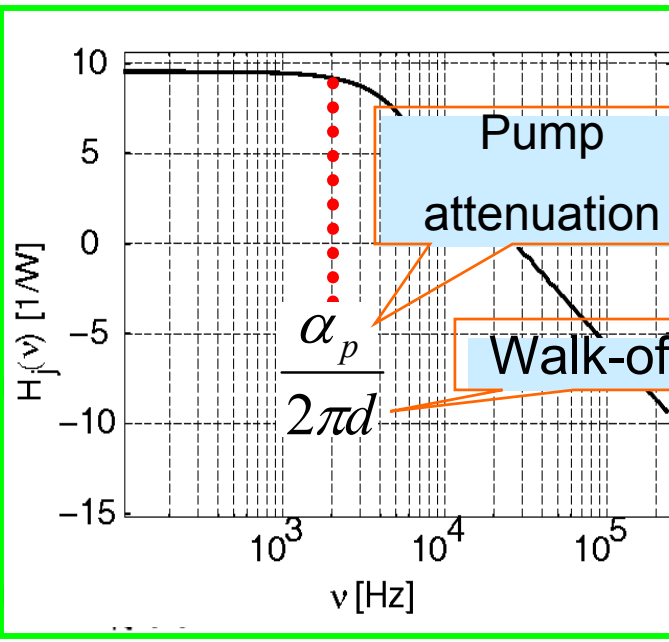


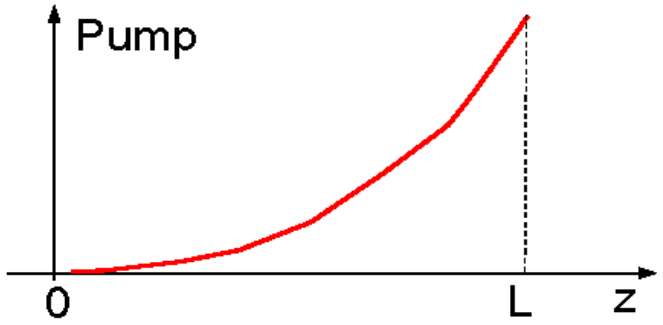
Pump depletion %



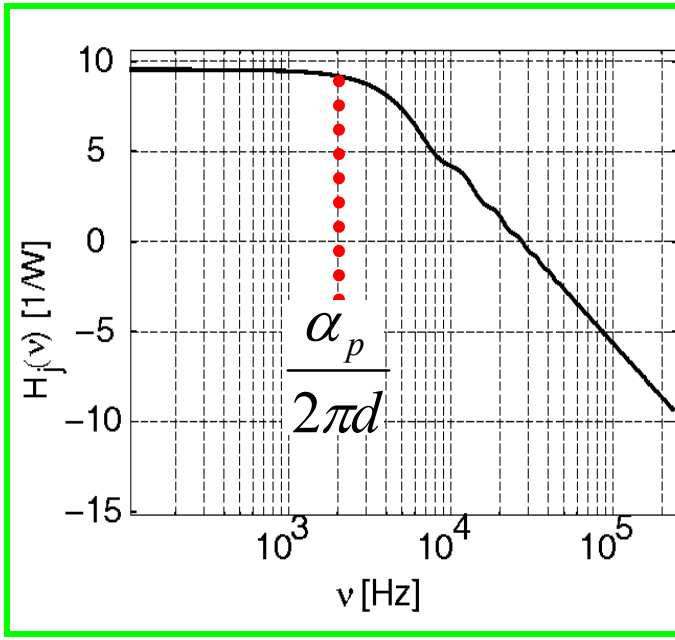
RAMAN AMPLIFIER BLOCK DIAGRAM

Filters:

depend on unsaturated pump profile



➢Closed-form formula available

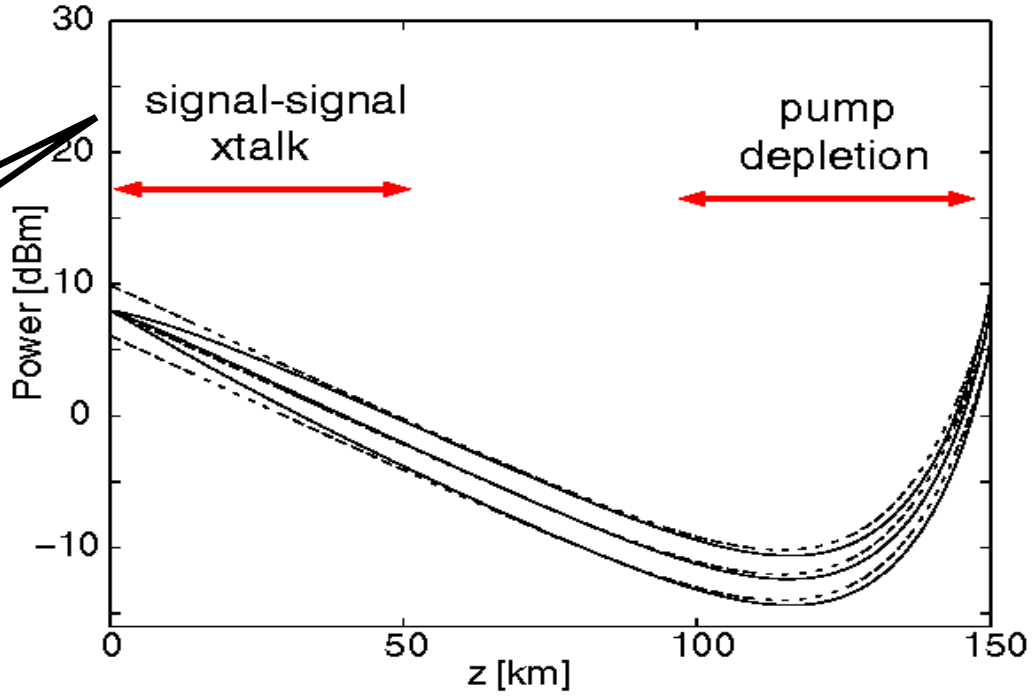


RAMAN AMPLIFIER BLOCK DIAGRAM

Assumptions

- ✓No signal-signal Raman Xtalk in amplification region

Direct signal-signal Raman xtalk can be easily added using known model



- ✓A. Bononi *et al.* El. Lett. July 01
- ✓D. N. Christodoulides *et al.* PTL Dec. 96

RAMAN AMPLIFIER BLOCK DIAGRAM

Assumptions

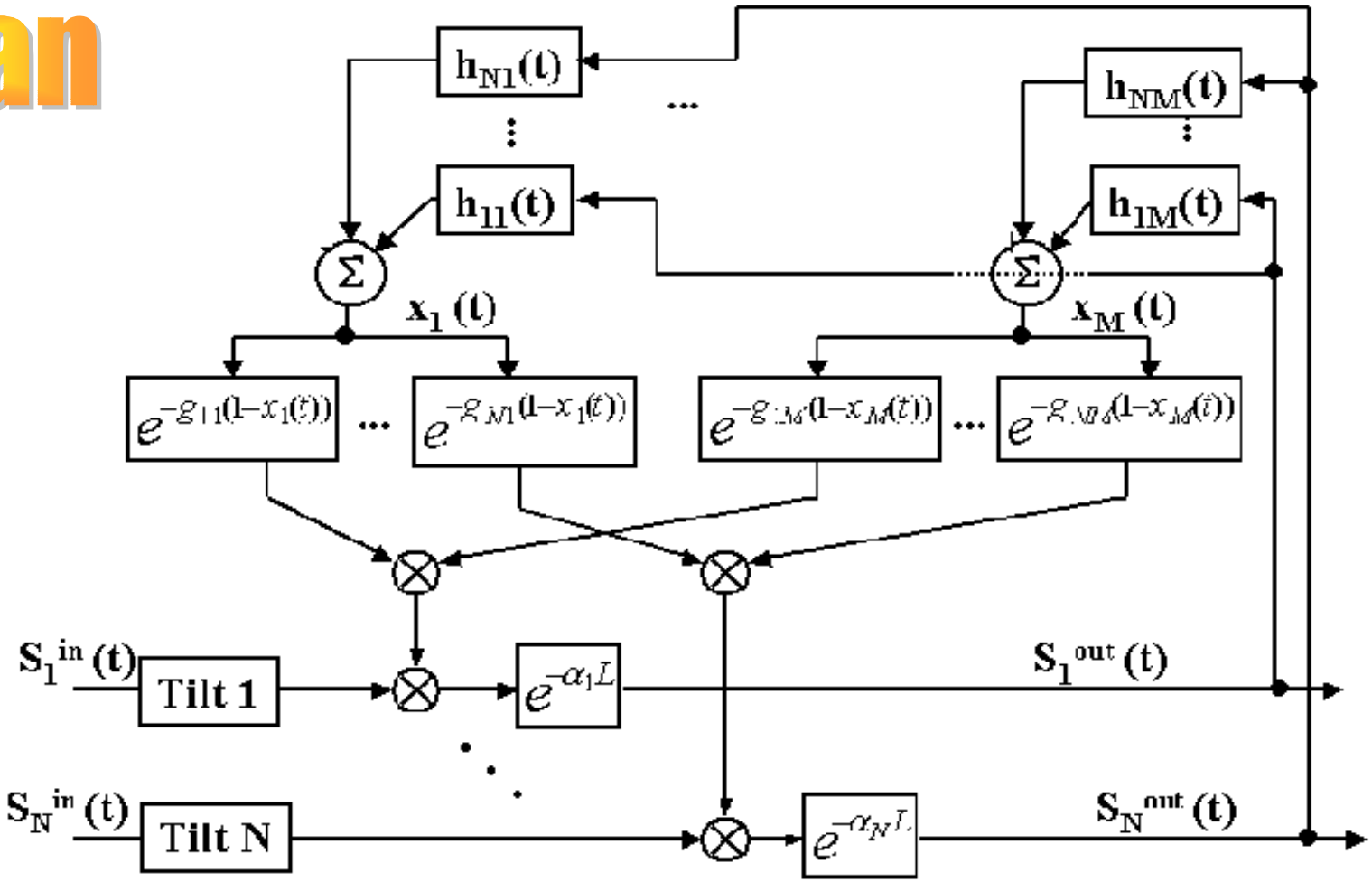
- ✓No signal-signal Raman Xtalk in amplifier
- ✓No noise (ASRS)
- ✓No Rayleigh backscattering (RBS)

Limits

- ✓Pump depletion < 30 %
- ✓Applicable only to backward pump

EXTENSION TO MULTIPLE PUMPS

Raman



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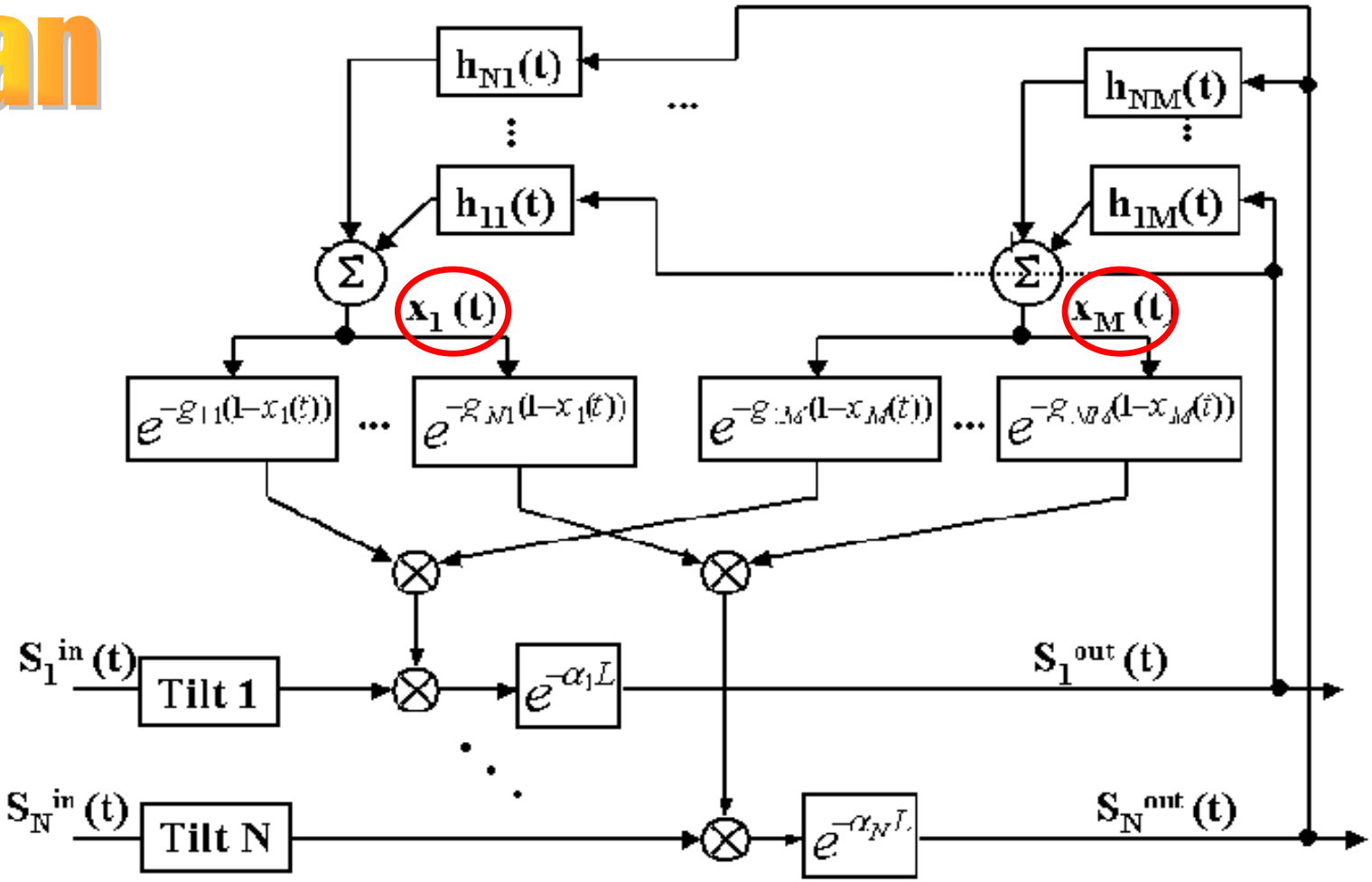

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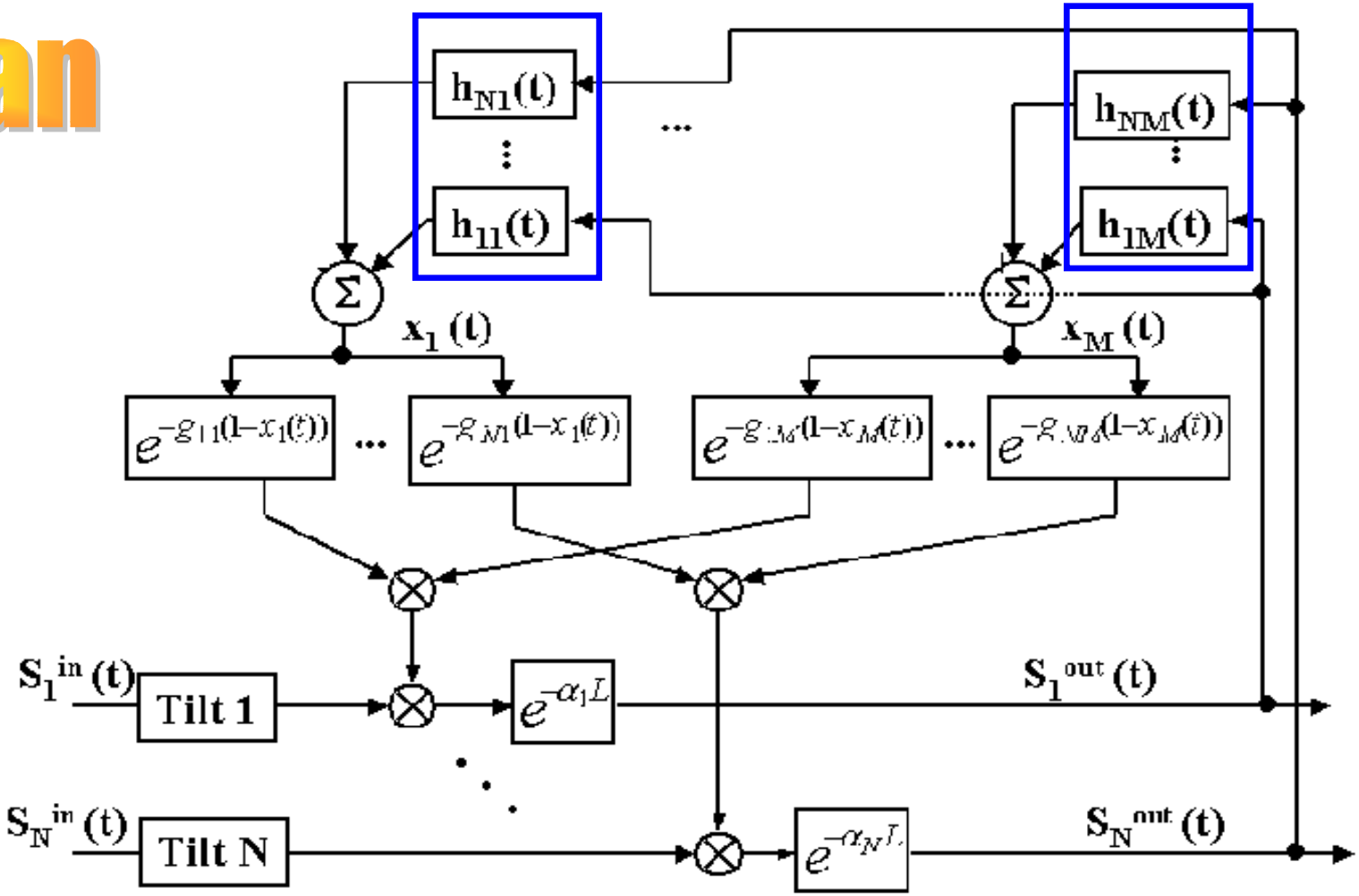

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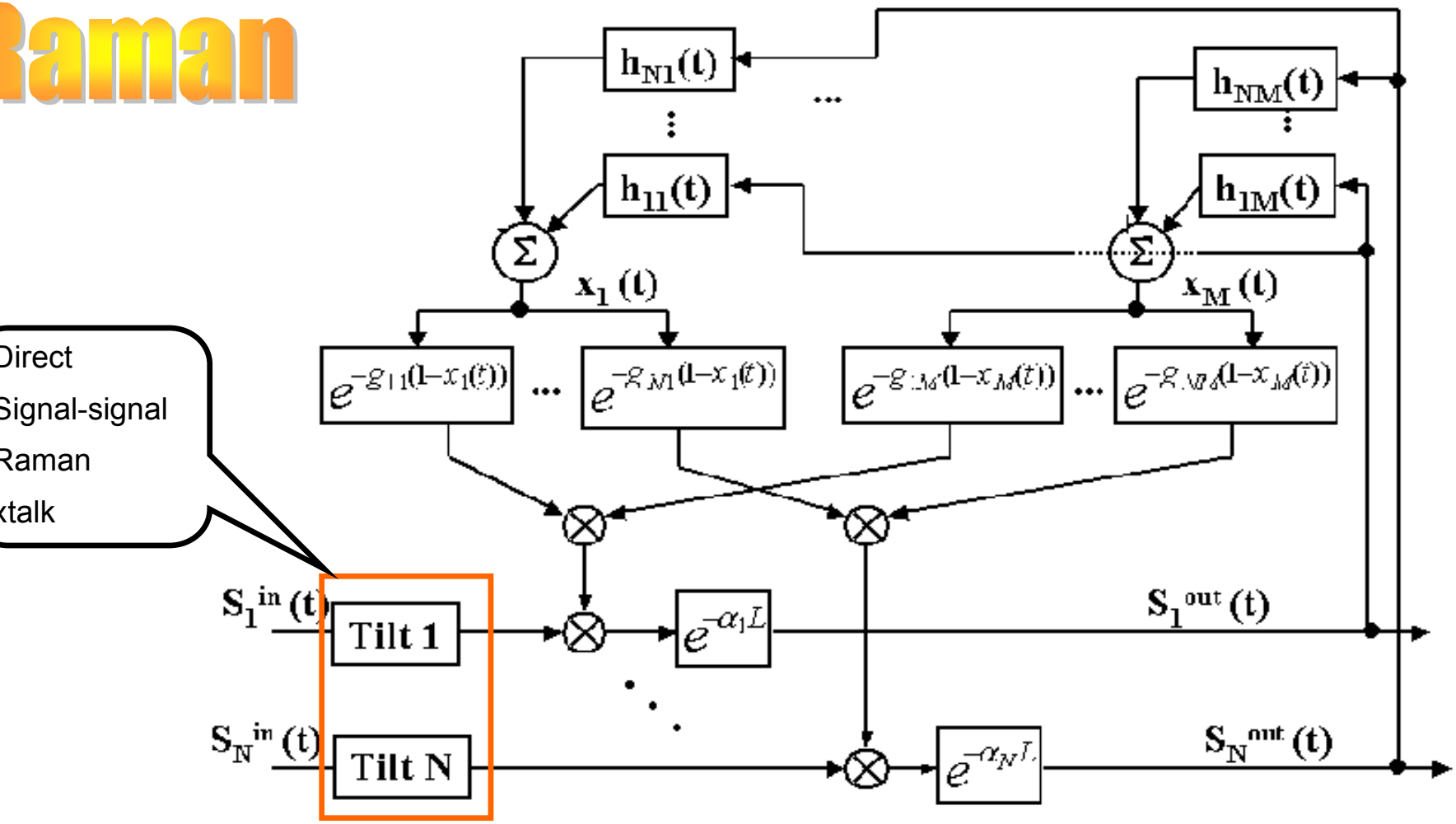

EXTENSION TO MULTIPLE PUMPS

Filters:

$$h_{jp}(t) = \frac{\gamma_{jp}\lambda_j / \lambda_p}{d\, G_j(L)} \frac{\left[\int_0^{L-\frac{t}{d}} \overline{P}_p(z')\, G_j(z'+\frac{t}{d})dz'\right]}{\left[\int_0^{L} \overline{P}_p(z')dz'\right]} \Pi\left(\frac{t-dL/2}{dL}\right)$$

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Raman coefficient

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Unsaturated gain

$$G_j(z) = \exp(-\alpha_j z + \sum_{p=1}^{M} \gamma_{jp} \int_0^z \overline{P}_p(z')dz')$$

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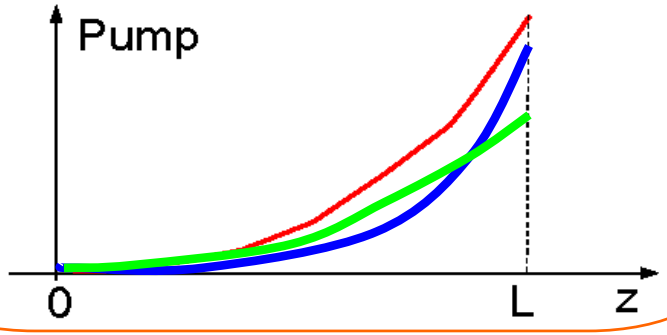
unsaturated pump profiles



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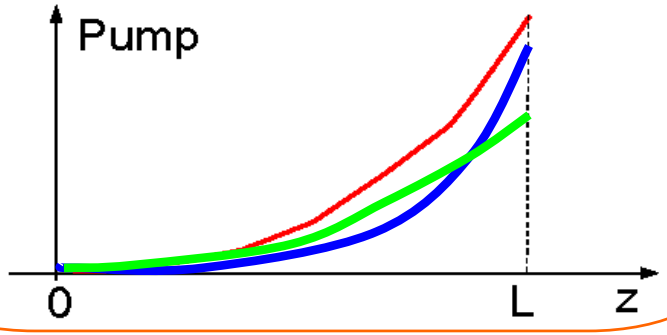
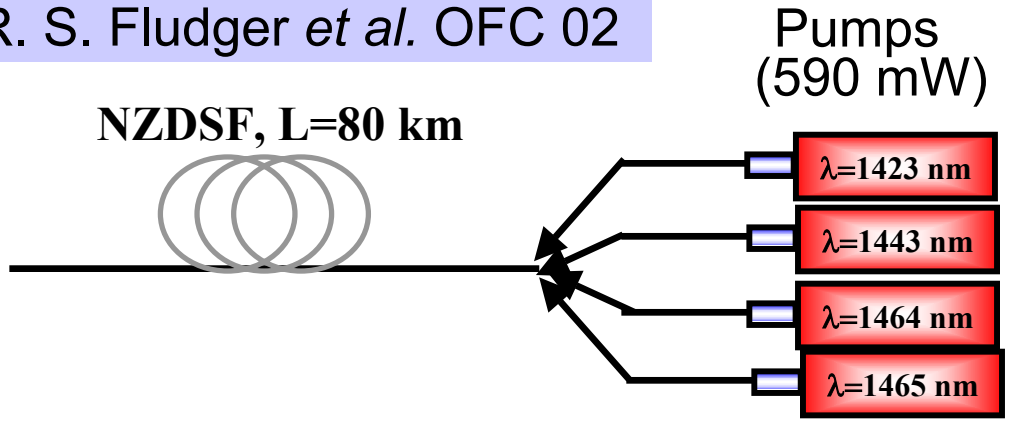


- Need to solve steady-state pump propagation equations to find $\overline{P}_p(z)$ (bias point)
- No closed-form filters formulae available

EXAMPLE: ultra-wide bandwidth system

✓C. R. S. Fludger *et al.* OFC 02



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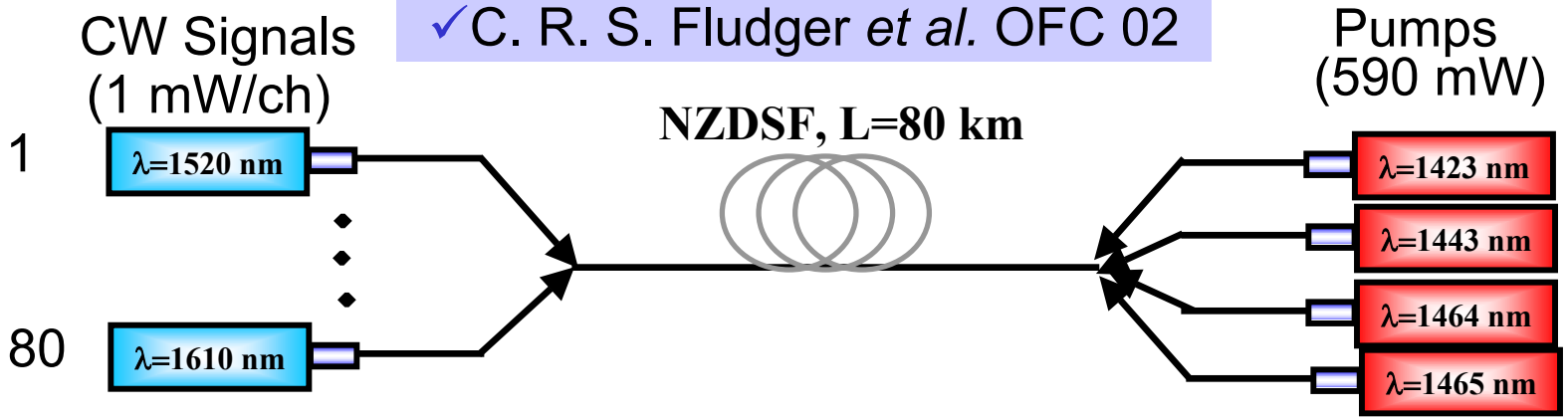

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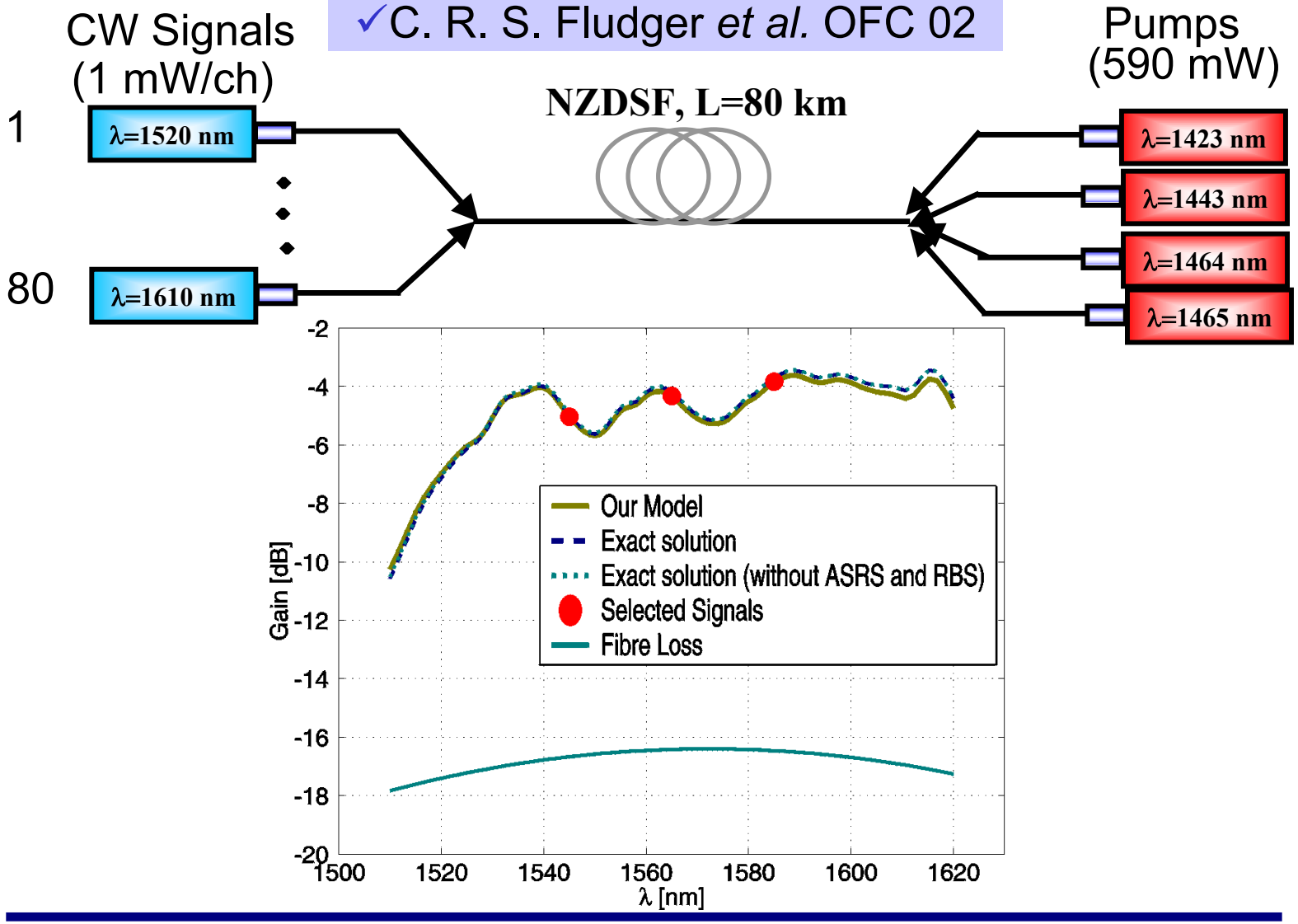

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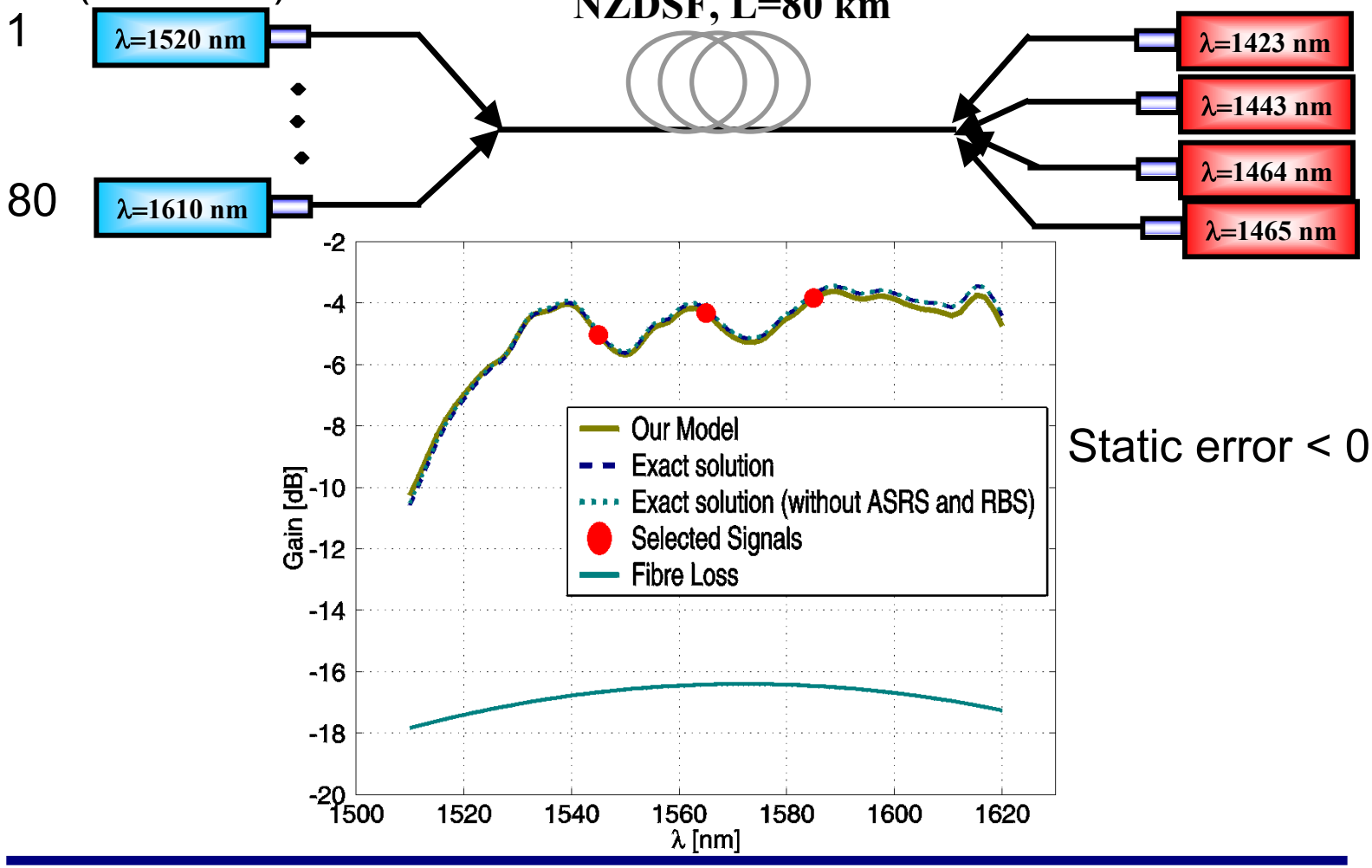
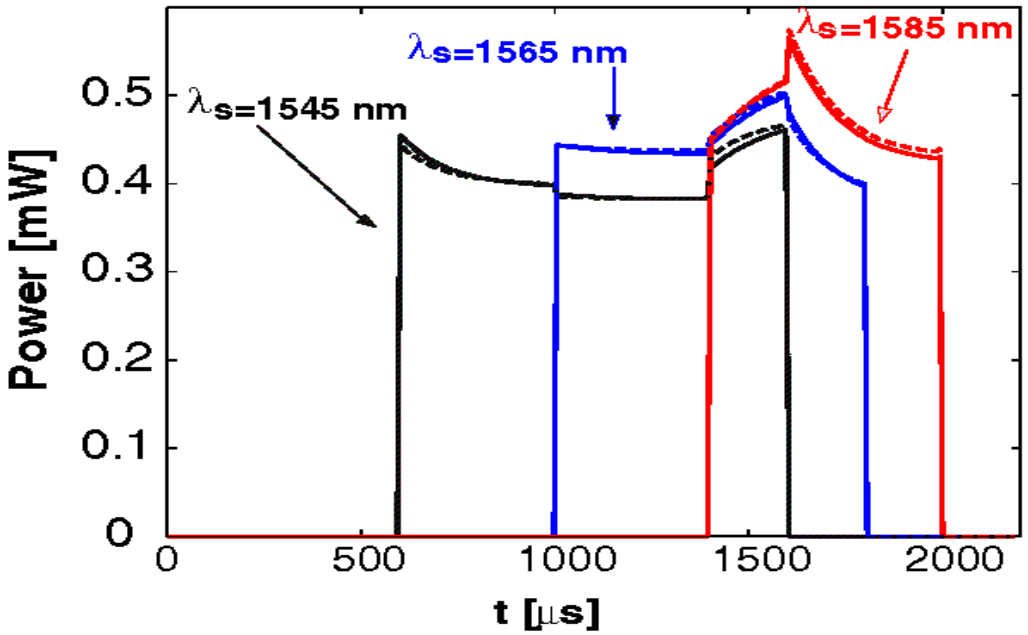


Static error < 0.3 dB

EXAMPLE: ultra-wide bandwidth system

- All 80 channels ON/OFF modulated, 1 mW ON power, slot time 200 μs



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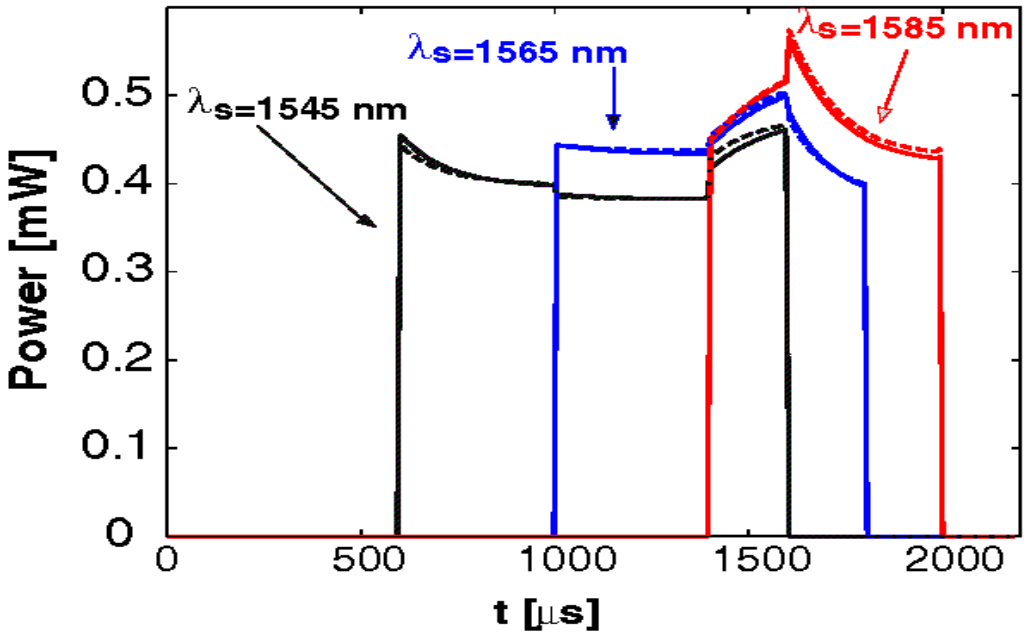

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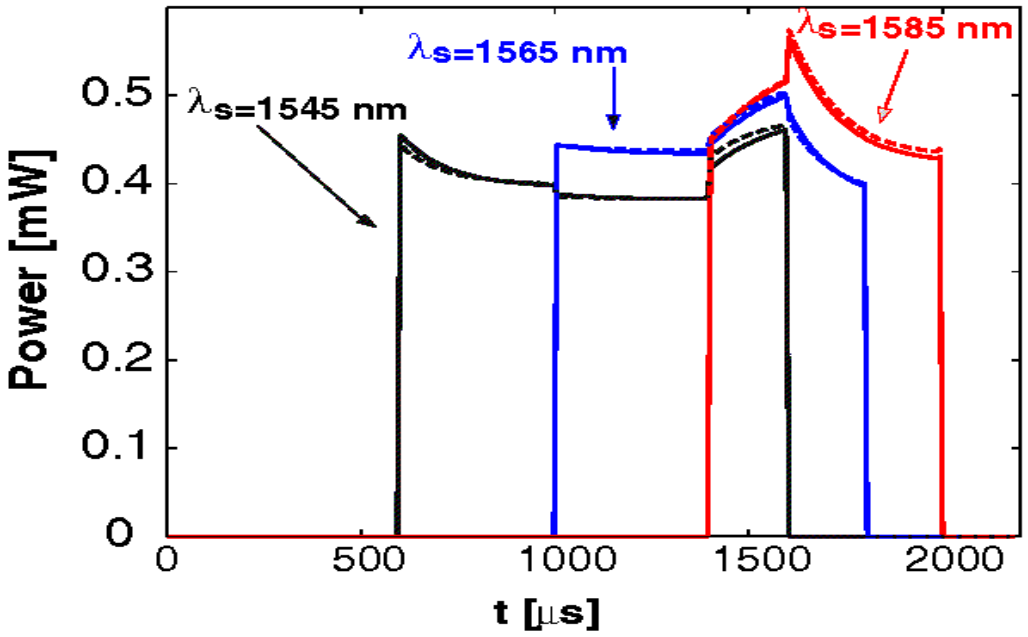


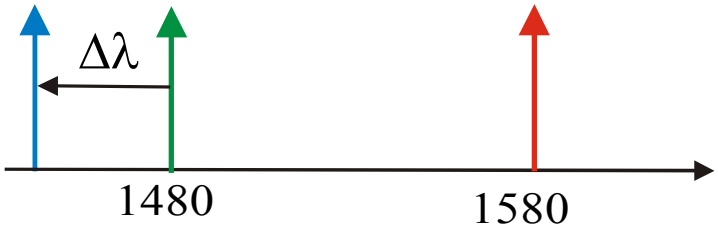
Dynamic error < 0.3 dB

- Computation time on a laptop:

  model: 2 min; exact: 2 hours!

LIMITS OF MULTIPUMP MODEL

- less accuracy with resonant pumping



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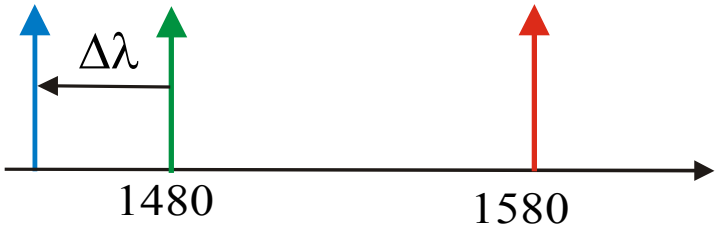

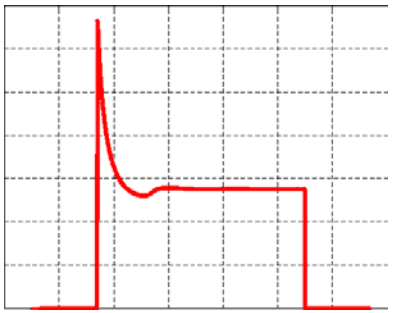

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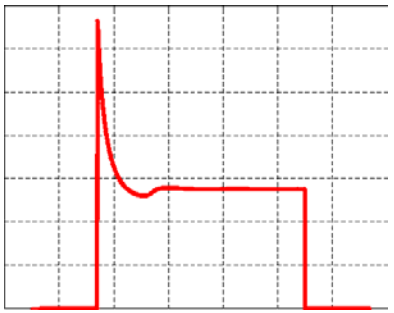

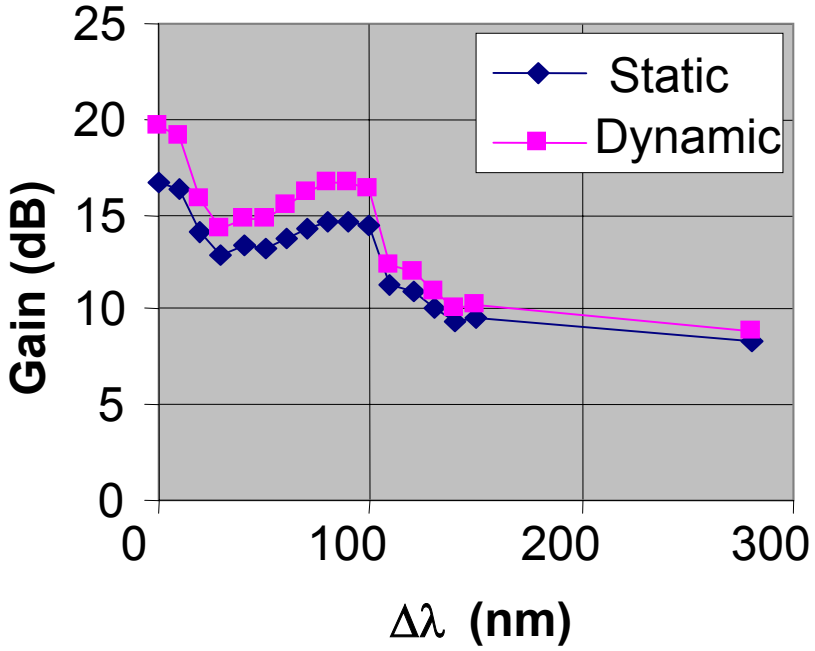

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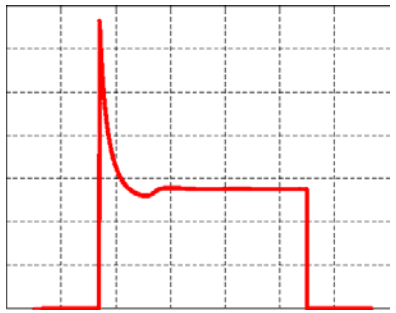

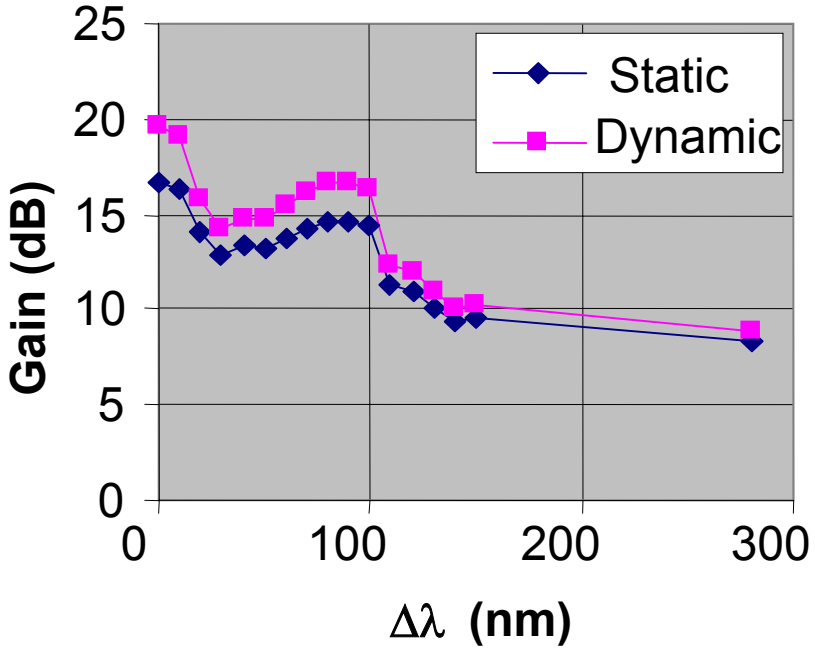

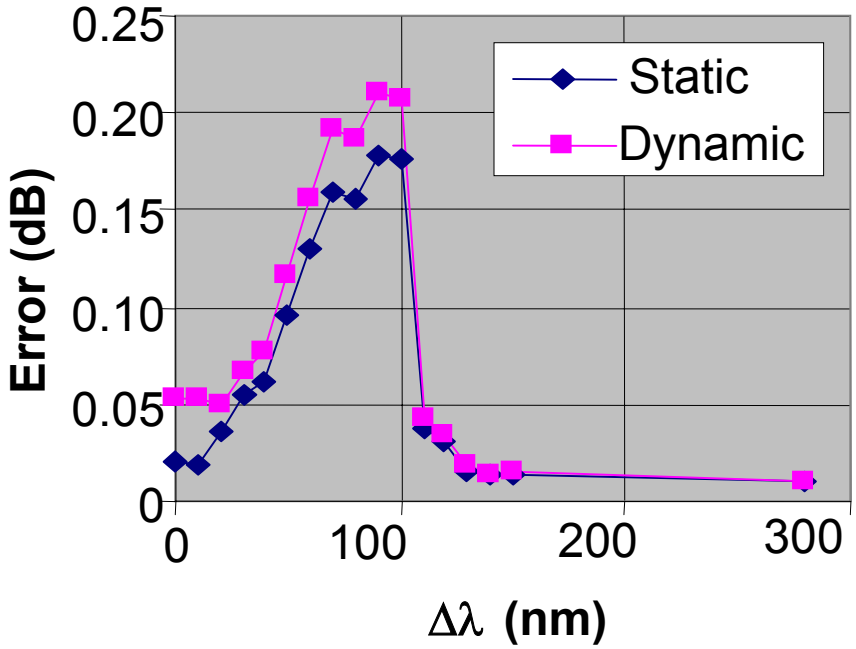

CONCLUSIONS

- Extended Raman amplifier block diagram to multiple pumps
- Large computational saving for large WDM systems
- Limits:
  - moderate pumps depletion < 30 %
  - less accurate with resonant pumping
  - works only for backward pumps