Nonlinear susceptibility

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Nonlinear polarisation

❑ Constitutive equations

$$\mathbf{D} = \varepsilon\mathbf{E} = \varepsilon_o\mathbf{E} + \mathbf{P},$$

$$\mathbf{P} = \varepsilon_o\chi\mathbf{E}$$

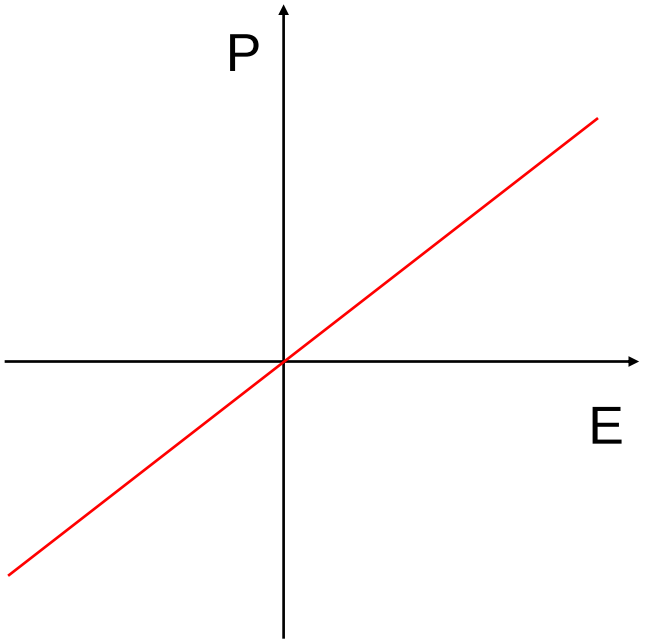
❑ Origin of nonlinear response

Related to anharmonic motion of bound electrons under the influence of an applied field.

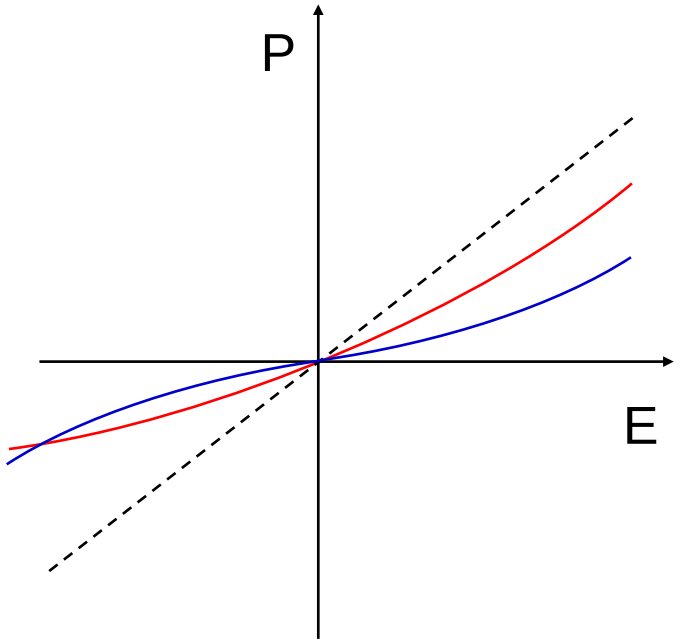
$$\mathbf{P} = \varepsilon_o\chi\mathbf{E} = \varepsilon_o\left(\chi^{(1)}\mathbf{E} + \chi^{(2)}\mathbf{EE} + \chi^{(3)}\mathbf{EEE} + \cdots\right)$$

Note: $\chi^{(2)}$ is non-zero only for media that lack an inversion symmetry (centrosymmetry).

Linear and nonlinear response

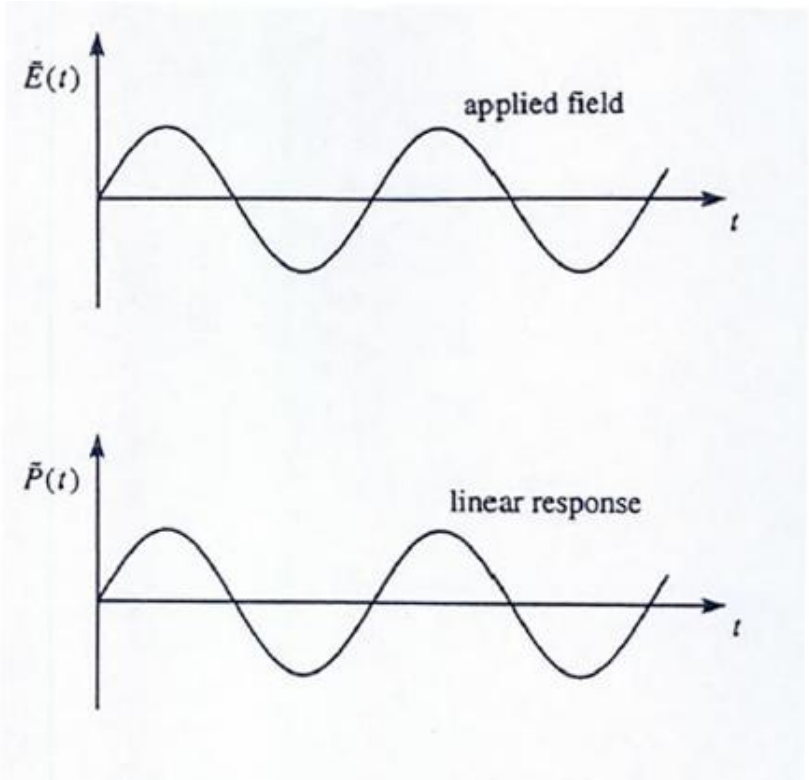


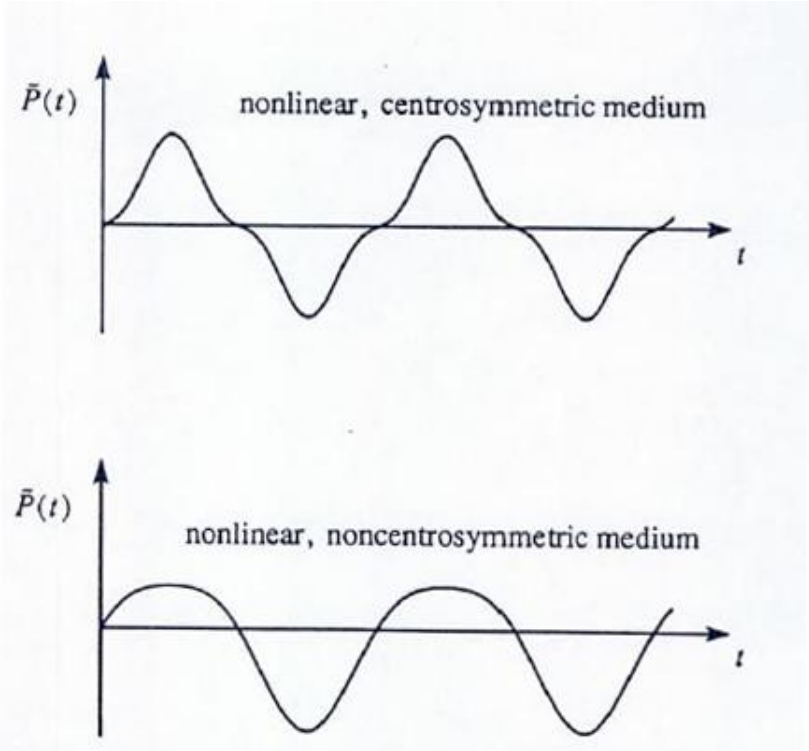
Linear medium



Nonlinear medium

Waveforms with the atomic response



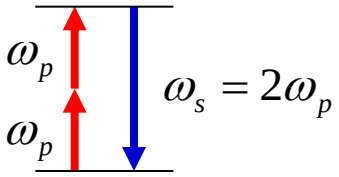


Source: Nonlinear Optics, R. W. Boyd, Chap. 1

Nonlinear interactions

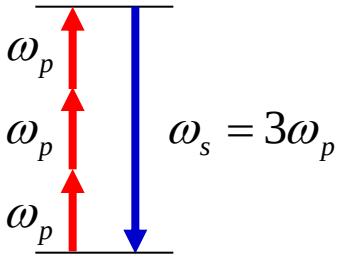
Second-order nonlinear interaction

- Linear (or Pockels) electro-optic effect
- Second-harmonic generation
- Sum frequency generation

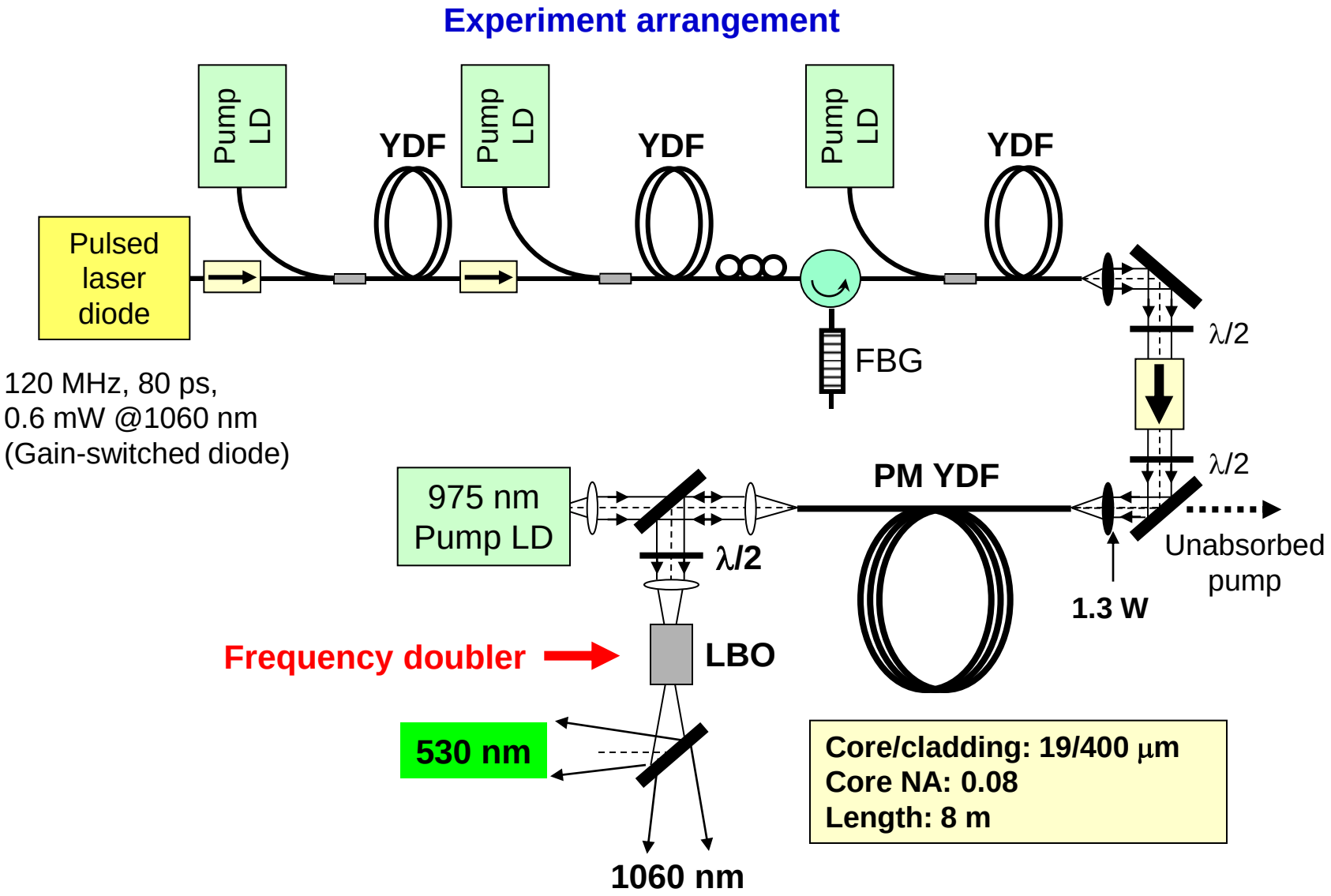


Third-order nonlinear interaction

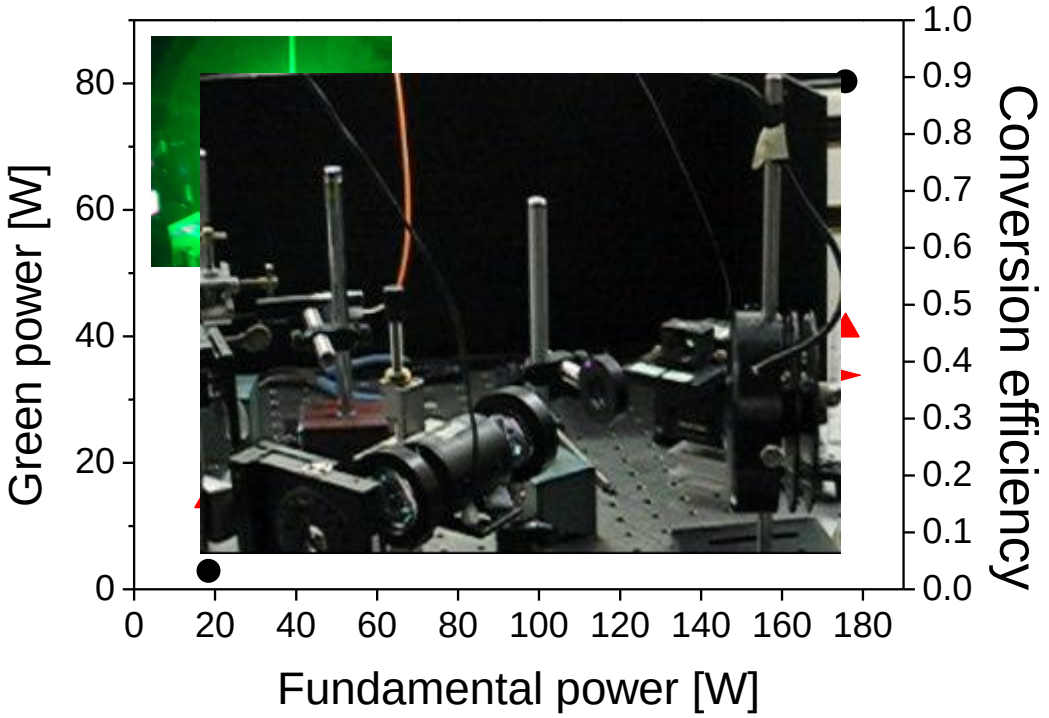
- Quadratic (or Kerr) electro-optic effect
- Third-harmonic generation
- Four-wave mixing
- Self-phase modulation
- Cross-phase modulation
- Self focusing

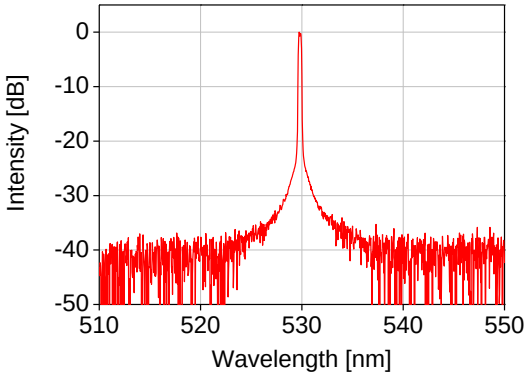


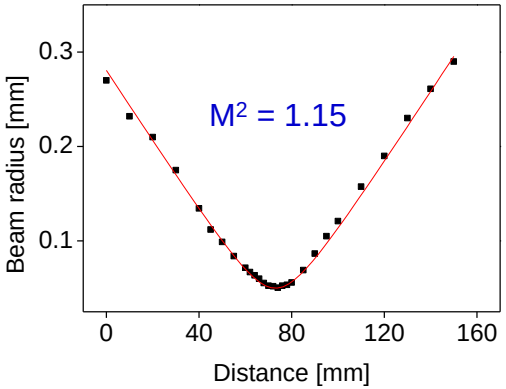
SHG based on a fibre MOPA at 1060 nm



Frequency doubled output at 530 nm





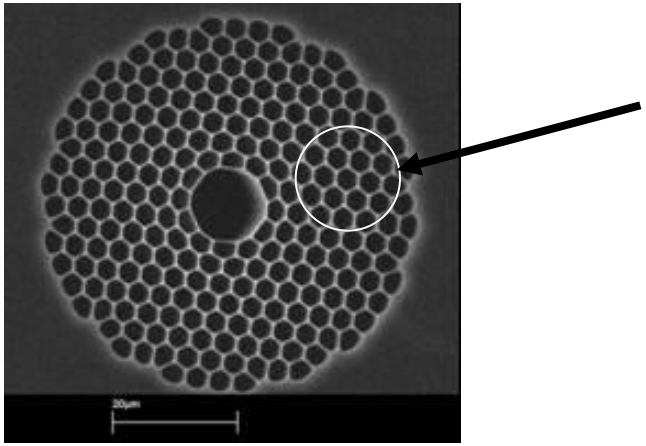


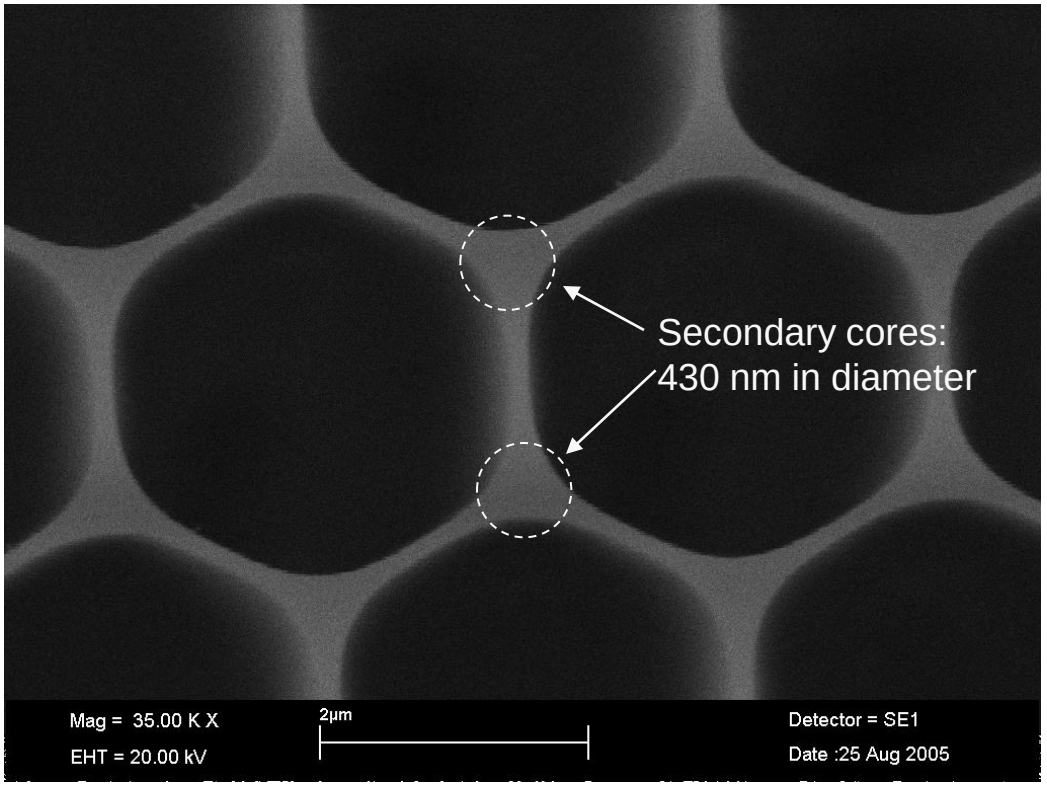
- **Maximum output power at 530 nm: 80 W**
- **Conversion efficiency: 46%**
- **Nearly diffraction limited beam: $M^2 = 1.15$**

Four-wave mixing in fibre

Fibre Parameters

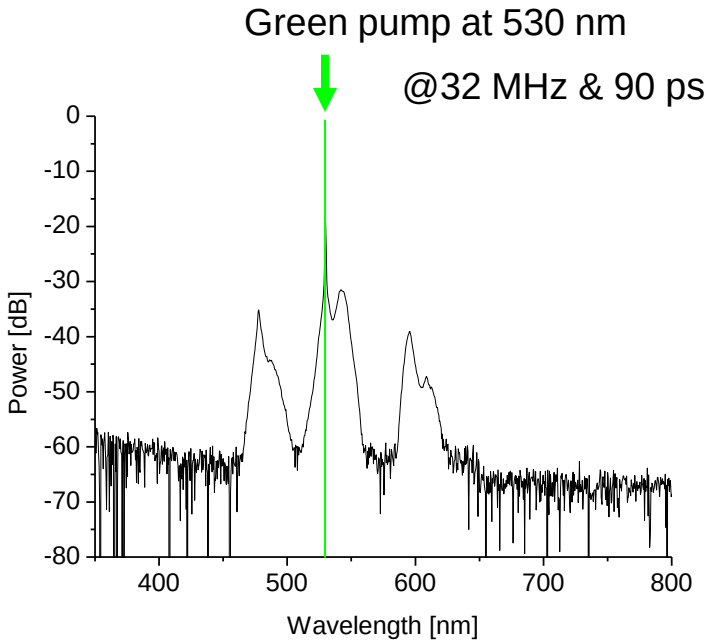
Structure: 7-point core defect, 7½ ring structure.
Hole-to-hole spacing: 3.6 μm
Hole diameter relative size (d/Λ): 0.95
Air filling factor: ~87%
Core diameter: 11.6 μm.
Fundamental bandgap: 1570 nm.
Higher order: 458, 505, 560 nm
(Fabricated from the resources outside the project)

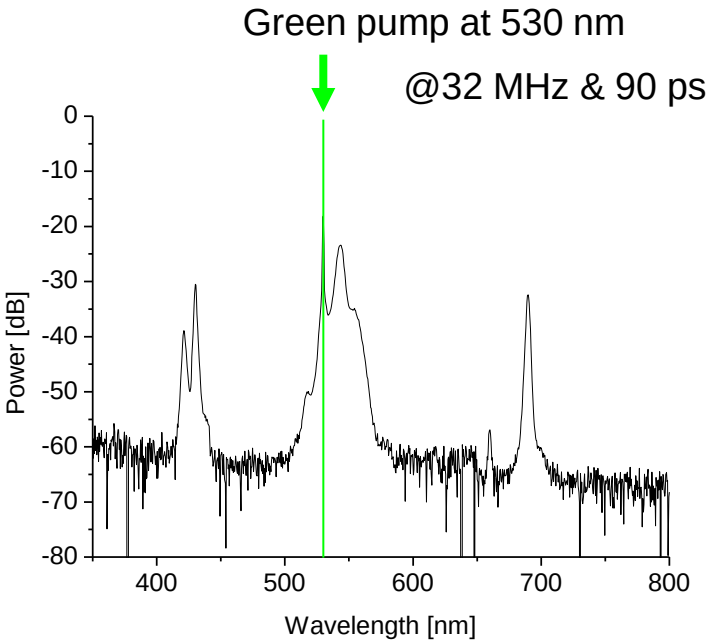




Secondary cores to be investigated for four-wave mixing!

RGB by four-wave mixing in fibre





Diffracted output image