Beam and Pulse shaping

Seminar on Ultrafast Optics

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Contents

Beam shaping

Beam shaping: Redistribution of the irradiance and phase of the laser beam

- Irradiance: defines beam profile (Gaussian, rectangular)
- Phase: Propagation properties

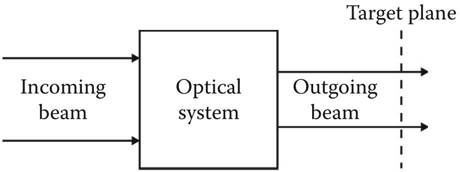


Fig.: Beam shaping problem [1].

[1] Dickey, F.M. and Holswade, Laser Beam Shaping: Theory and Techniques, 2010

Beam shaping

Aim: Convert Gaussian beam profile into a rectangular profile

1. Beam aperture: Selection of flat portion of the beam

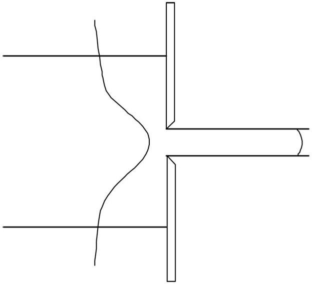


Fig.: Aperturing of the beam [1].

[1] Dickey, F.M. and Holswade, Laser Beam Shaping: Theory and Techniques, 2010

Beam shaping

Aim: Convert Gaussian beam profile into a rectangular profile

1. Beam aperture: Selection of flat portion of the beam
2. Field mapping: transforms single mode beam into a uniform beam, effectively lossless

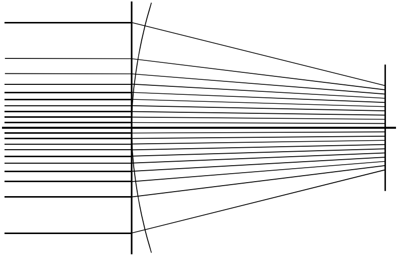


Fig.: Field mapping concept [1].

[1] Dickey, F.M. and Holswade, Laser Beam Shaping: Theory and Techniques, 2010

Beam shaping

Aim: Convert Gaussian beam profile into a rectangular profile

1. Beam aperture: Selection of flat portion of the beam
2. Field mapping: transforms single mode beam into a uniform beam, effectively lossless
3. beam integrators: Beam split by lenslet array, suited for multimode lasers, lossless

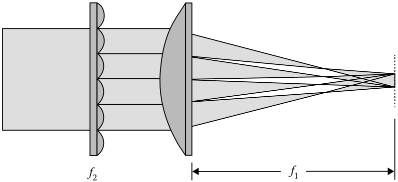


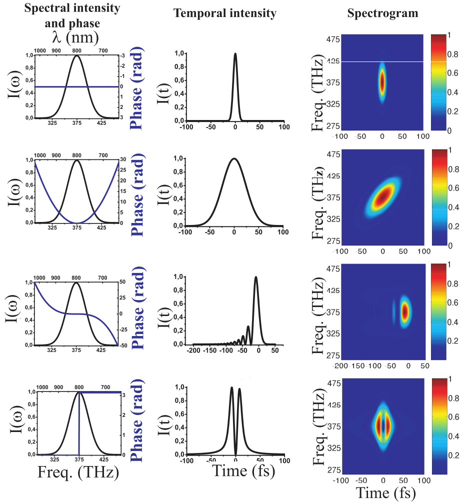
Fig.: Beam integrator [1].

[1] Dickey, F.M. and Holswade, Laser Beam Shaping: Theory and Techniques, 2010

Pulse shapes

Fig.: Pulse shaping gallery: [1]

a): Fourier transform pulse
b): chirped pulse
c): cubic phase
d): spectral π-jump



[1] Monmayrant A, et. al: A newcomers guide to ultrashort pulse shaping and characterization, 2010

Pulse shaping

Basis: linear time invariant filter described by a transfer function $H(\omega)$

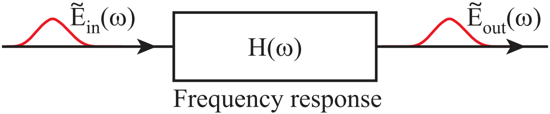


Fig.: Linear filtering and Transfer function $H(\omega)$ [1].

Simple pulse shaping techniques:

1. Michelson Interferometer

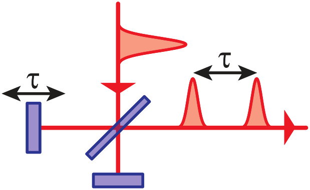


Fig.: Michelson Interferometer [1].

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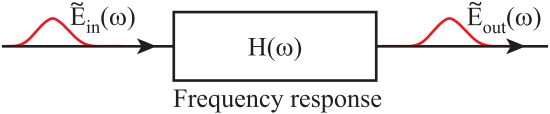

Fig.: Linear filtering and Transfer function $H(\omega)$ [1].

Simple pulse shaping techniques:

1. Michelson Interferometer
2. Dispersive bulk medium

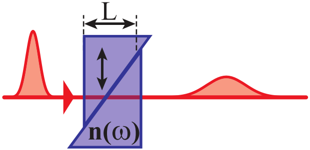

Fig.: Bulk medium [1].

[1] Monmayrant A, et. al: A newcomers guide to ultrashort pulse shaping and characterization, 2010

Pulse shaping

Basis: linear time invariant filter described by a transfer function $H(\omega)$

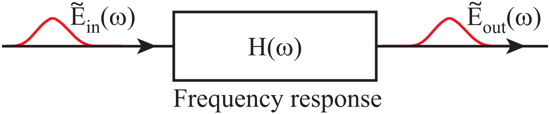

Fig.: Linear filtering and Transfer function $H(\omega)$ [1].

Simple pulse shaping techniques:

1. Michelson Interferometer
2. Dispersive bulk medium
3. Grating compressor

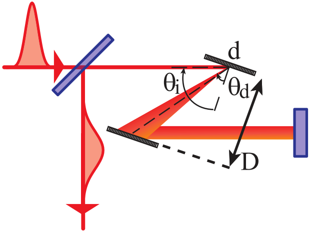

Fig.: Grating compressor [1].

[1] Monmayrant A, et. al: A newcomers guide to ultrashort pulse shaping and characterization, 2010

Pulse shaping

Basis: linear time invariant filter described by a transfer function $H(\omega)$

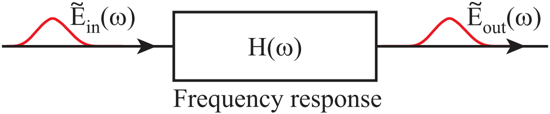

Fig.: Linear filtering and Transfer function $H(\omega)$ [1].

Simple pulse shaping techniques:

1. Michelson Interferometer
2. Dispersive bulk medium
3. Grating compressor
4. Chirped mirror

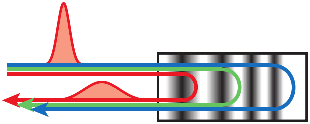

Fig.: Chirped mirror [1].

[1] Monmayrant A, et. al: A newcomers guide to ultrashort pulse shaping and characterization, 2010

Zero dispersion line (Froehly 1983)

composed of two *gratings* and two *lenses* arranged in a 4f-setup

- 1st grating: Angular dispersion of spectral components
- Fourier plane: Spatial separation and focusing
- 2nd grating: recombination into a single collimated beam

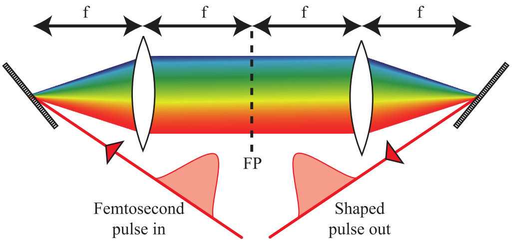

Fig.: Zero dispersion line [1].

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Zero dispersion line (Froehly 1983)

composed of two *gratings* and two *lenses* arranged in a 4f-setup

- 1st grating: Angular dispersion of spectral components
- Fourier plane: Spatial separation and focusing
- 2nd grating: recombination into a single collimated beam

- Modification of the optical path: Insert a **mask** into the FP ⇒ modfied density of spectral components

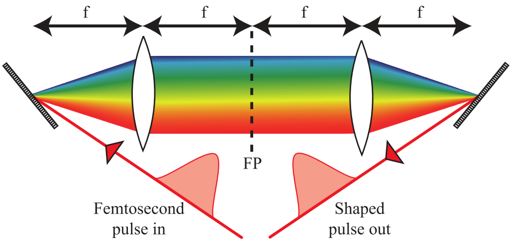

Fig.: Zero dispersion line [1].

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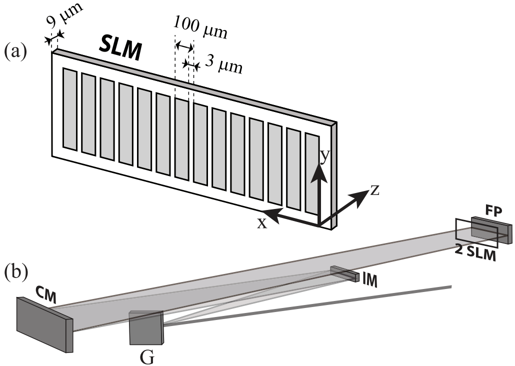
Masks: Liquid crystal spatial light modulator

- programmable waveplate controlled by voltage
- Structure: thin layer of (nematic) liquid crystal between two substrates
- Voltage: Change of the birefringence ⇒ optical path modification

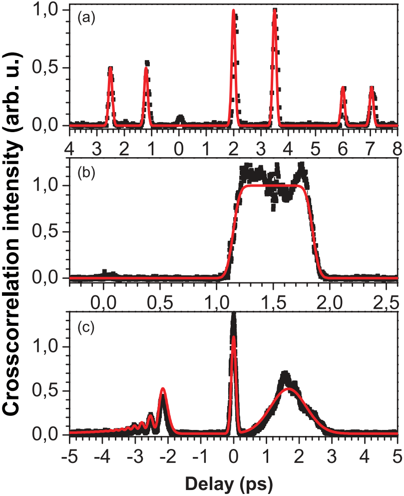
Fig.: a): 640 pixel spatial light modulator [1]
b): zero dispersion line geometry [1]



[1] Monmayrant A, et. al: A newcomers guide to ultrashort pulse shaping and characterization, 2010

Liquid crystal spatial light modulator (Experiment)

Fig.: Experimental waveforms: [1]
a): 3 pulse pairs with different intensities
b): Square pulse 700 fs FWHM
c): 3 pulses with cubic, flat and quadratic phase

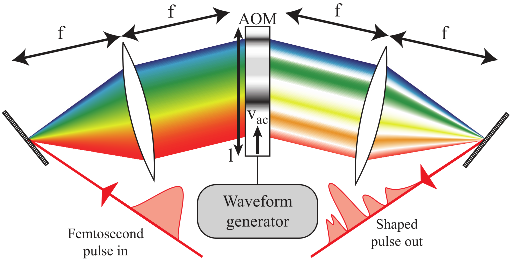


[1] Monmayrant A, et. al: A newcomers guide to ultrashort pulse shaping and characterization, 2010

Masks: Acousto-optic modulator

- transparent crystal driven by a radiofrequency voltage signal
  ⇒ converted to an acoustic wave by pioezoelectronics
  ⇒ Acts as a refractive index grating
- Spatial dispersion of the frequency compoenents

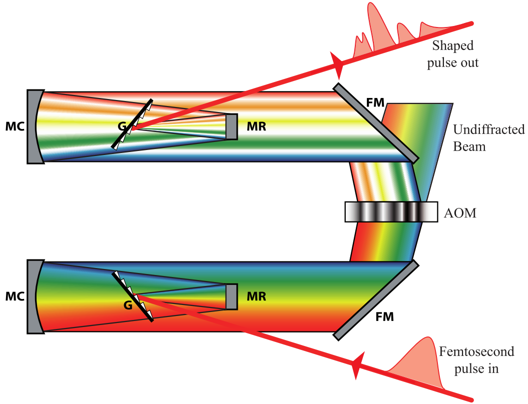
Fig.: a): 640 pixel spatial light modulator [1]
b): zero dispersion line geometry [1]



[1] Monmayrant A, et. al: A newcomers guide to ultrashort pulse shaping and characterization, 2010

Acousto-optic modulator (Experiment)

Fig.: Experimental setup of a 4f-line with AOM spatial mask [1]
FM: Folded mirrors
MR: Intermediate mirror
MC: Concave mirror



[1] Monmayrant A, et. al: A newcomers guide to ultrashort pulse shaping and characterization, 2010

Phase transfer

- frequency mixing between the input pulse and an acoustic or optical control field in a highly *birefringent crystal*
  ⇒ Interaction similar to Bragg diffraction
- Acoustic wave creates longitudinal temporary grating

- Ordinary optical wave diffracted to extradordinary axis (different for each spectral component) ⇒ different arrival time for each wavelength

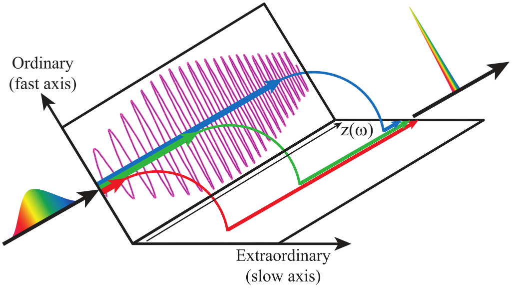


Fig.: Acousto-optic programmable dispersive filter (AOPDF) [1]

[1] Monmayrant A, et. al: A newcomers guide to ultrashort pulse shaping and characterization, 2010

Conclusion

Thank you for your attention.

Literature recommendations:

- Monmayrant A, et. al: **A newcomers guide to ultrashort pulse shaping and characterization**, 2010
- Dickey, F.M. and Holswade, Laser Beam Shaping: Theory and Techniques, 2010