Pulse shaping using a spatial light modulator

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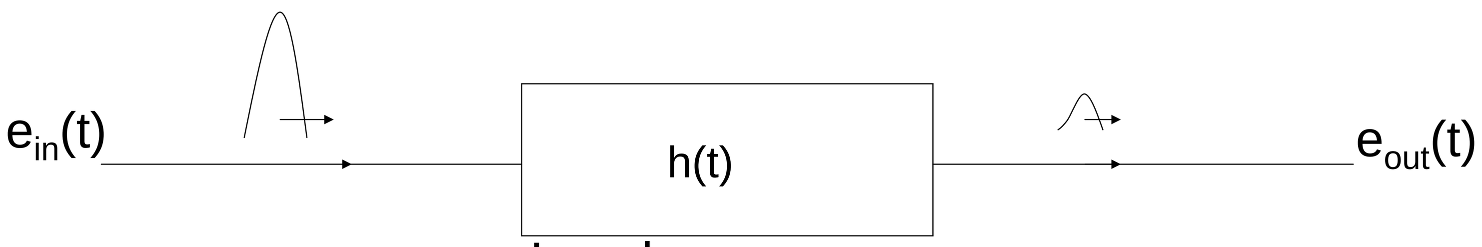
INTRODUCTION

Femtosecond pulse shaping can be done by different kinds of pulse shapers, such as liquid crystal spatial light modulators (LC SLM), acousto optic modulators (AOM) and deformable and movable mirrors. A few applications where pulse shaping is implemented are coherent control of molecules, communication systems, encoding and decoding and biomedical imaging.

THEORY OF PULSE SHAPING

In the time domain the output of the filter (shaper) is $e_{out}(t)$, and the input is $e_{in}(t)$. h(t) represents the input response function[1].

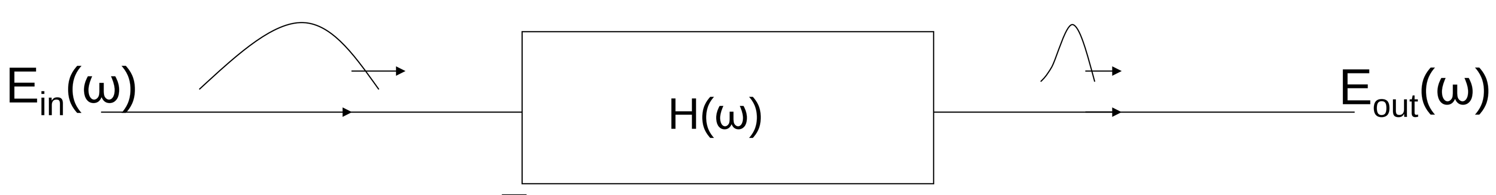
$$e_{out}(t) = e_{in}(t) * h(t) = \int dt' e_{in}(t')h(t-t')$$



Impulse response

In the frequency domain the filter is characterised by its frequency response H(ω). The output of the linear filter $E_{out}(\omega)$ is the product of the input signal and response function[1].

$$E_{out}(\omega) = E_{in}(\omega)H(\omega)$$



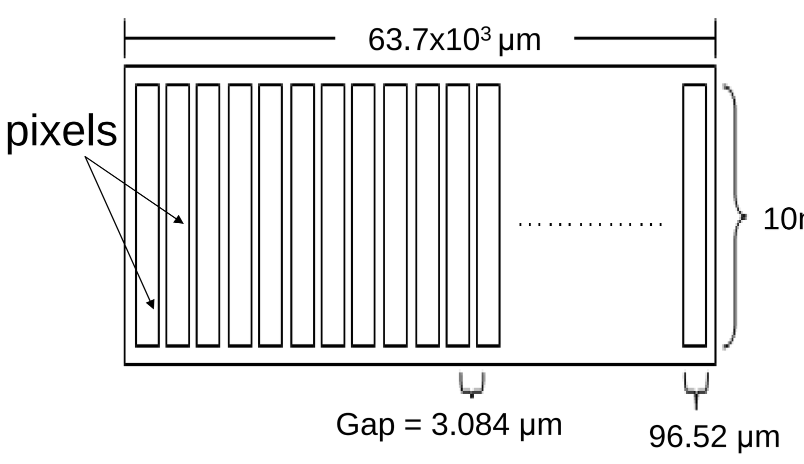
Frequency response

$e_{out}(t)$, $e_{in}(t)$, h(t) and $E_{out}(\omega)$, $E_{in}(\omega)$, H(ω) respectively are Fourier transforms of each other.

$$H(\omega) = \int dt h(t) e^{i\omega t}, \quad h(t) = \frac{1}{2\pi}\int d\omega H(\omega) e^{i\omega t}$$

LIQUID CRYSTAL SPATIAL LIGHT MODULATOR (LC SLM)

The most popular pulse shapers are the acousto optic modulator and the liquid crystal spatial light modulator.



PULSE SHAPER SETUP DESIGN

The pulse shape setup that is most commonly used is the 4f design (see figure 1). There are different variations of the 4f setup of which some are more compact[2] (see figure 2).

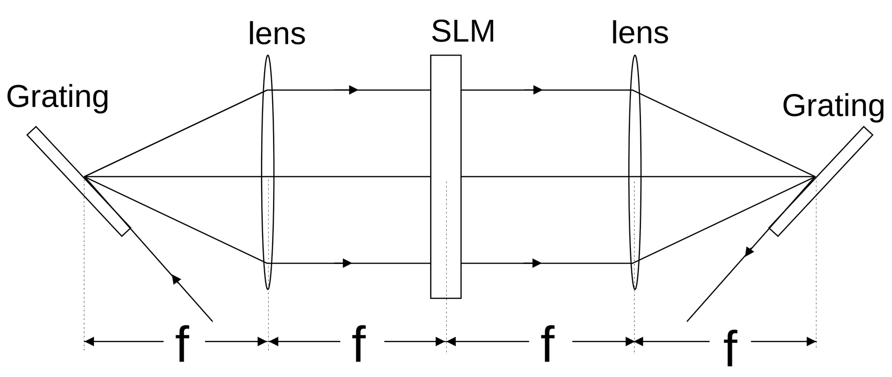


Fig1. 4f Design

Resolution:

$$\frac{\lambda\, spread}{length\ of\ SLM} = \frac{44\,\text{nm}}{63.7\times10^{3}\mu\text{m}}$$
$$= 0.000691\ nm/\mu m$$
$$0.000691 \times length\ of\ pixel$$
$$= 0.0667\ nm/pixel$$

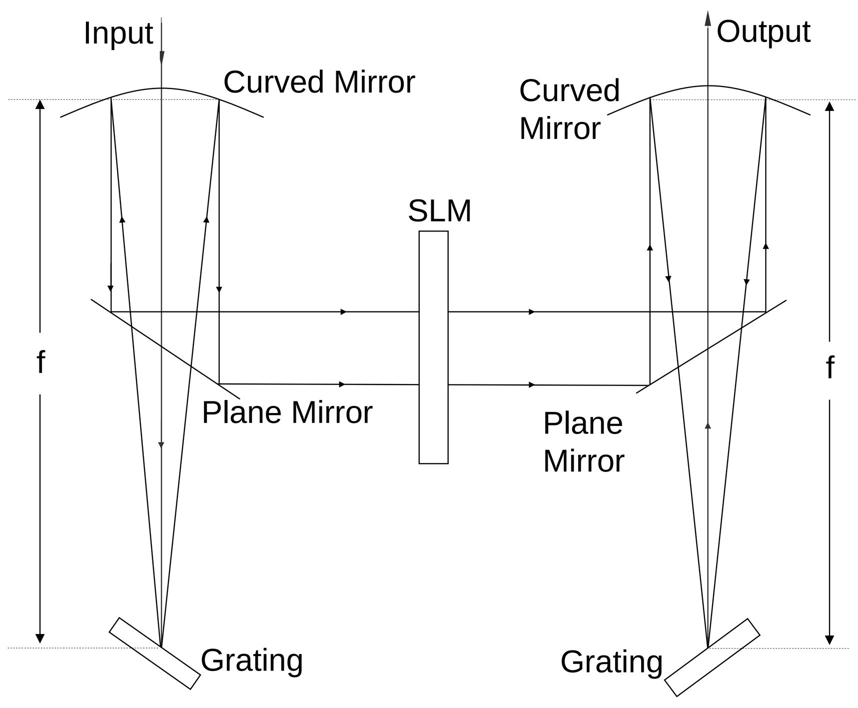


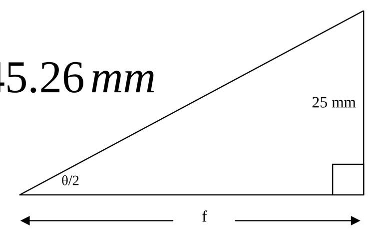
Fig2. Compact design

Focus length necessary for a sufficient angular dispersion to illuminate the whole SLM:

$$\frac{d\lambda}{d\theta} = \frac{nm}{\cos\theta}$$

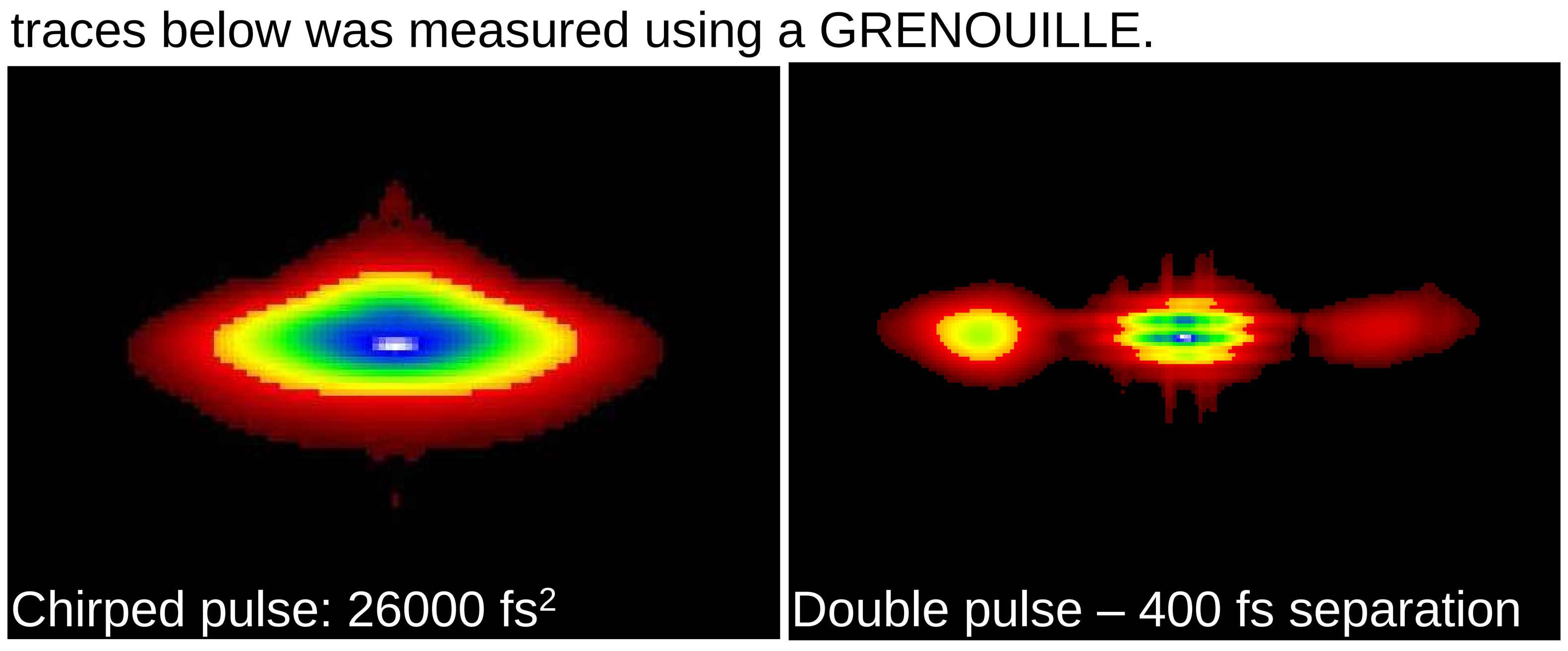
n = grating groove density
m = light order = 1

$$\int \cos\theta\, d\theta = \int nm\, d\lambda$$
$$\sin\theta = nm\Delta\lambda = (1200\times10^{3})(44\times10^{-9})$$
$$\theta = 3.03$$
$$f = \frac{25mm}{\tan(\theta/2)} = 945.26\,mm$$



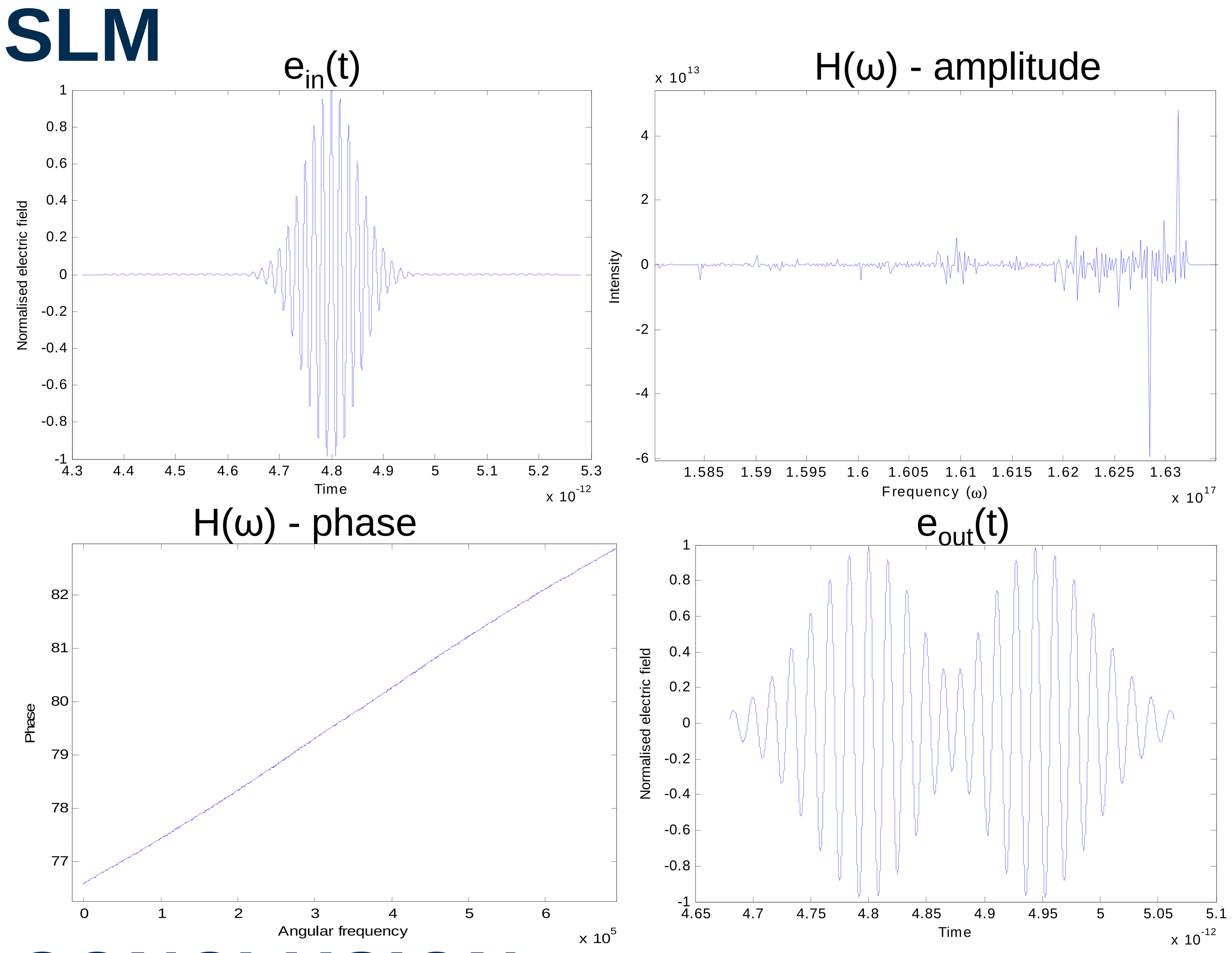
PULSE SHAPING USING AN AOM

An acousto optic modulator uses sound wave to form a grating. The velocity of the sound wave is so much slower than that of the incoming light, that the grating appears stationary to the light. The two traces below was measured using a GRENOUILLE.



The trace in the second figure should correspond to a double pulse but is slightly misaligned in this case.

SIMULATION: SHAPING WITH A SLM



CONCLUSION

We are going to use the LC SLM for our pulse shaper. The compact design in figure 2 is preferred for our setup due to the smaller size and good accessibility to the optical components.

BIBLIOGRAPHY

1. A. M. Weiner, “Femtosecond pulse shaping using spatial light modulators," Review of scientific instruments. 71, 1929-1960 (2000).
2. A. Präkelt, M. Wollenhaupt, A. Assion, Ch. Horn, C. Sharpe-Tudoran, M. Winter and T. Baumert, “Compact, robust, and flexible setup for femtosecond pulse shaping,“ Review of scientific instruments. 75, 4950-4953 (2003).