Appendix A

Alignment of the Pulse Shaping Apparatus

The central element in this work is the pulse shaping apparatus, which is indispensable for generating ultrafast waveforms. In the generated Fourier plane, the pulse spectrum is split in different frequency components in order to modulate the corresponding amplitude and phase. The quality of the pulse shapes depends strongly on the proper alignment. This appendix gives some hints in order to precisely align the pulse shaper setup, but should not be considered as a standard method for all pulse shapers. In the following it is assumed that the liquid crystal mask is placed on a flat surface, or on the optical table and a stable femtosecond laser is chosen as light source.

1. If you use the cylindrical lenses, reduce the beam diameter of the laser (e.g. with and telescope) to approx. 2–3 mm before entering the pulse shaper setup.

2. Align the laser beam before the first grating parallel to the optical table and at the same height as the liquid crystal mask. In this way the optical axis is fixed.

3. Set the two lenses to $2f$ distance. Align this distance to the minimal divergence of the laser beam.

4. Place the first grating at $-f$ away from the first lens onto the optical axis. Align its height so that the transmitted beam propagates with the table surface. Set the surface and the rulings of the grating perpendicularly to the optical table. This is already done when the zero-order diffraction (specular reflection) and the first diffraction order are parallel with the optical table. In this way, the direction of the desired dispersion (in which the frequency components spread) is parallel with the optical table, as well.

5. Place the second grating at $+f$ away from the second lens, maintaining the optical axis. Align the tilt and the direction of the grating rulings like

described in step (4). The position of the grating must be symmetrical with respect to the first grating. This means that no spatial dispersion remains, i.e. all the frequency components are perfectly overlapped. In order to achieve this, (i) change the angle between the grating and the optical axis and (ii) observe the output beam in the far field. To help visualize the residual dispersion (spatial chirp) place a card in the Fourier plane (where the liquid crystal modulator is going to be mounted) and sweep it across the spatially dispersed frequencies. If the residual dispersion is present, the image of the card is sweeping across the output beam. If the intensity of the output beam is uniformly attenuated in the far field as the card is swept in the Fourier plane, there is no spatial chirp in the pulse shaper setup.

6. Set the distance between the two gratings exactly at $4f$ so that the group velocity dispersion is zero. (This may vary if the input pulse is already chirped.) In order to reduce the temporal chirp, slide the second grating along the optical axis. For every position of the second grating, measure the output pulse duration, e.g. with the F.R.O.G. technique or intensity cross-correlation, using an unshaped pulse as reference, in order to minimize the temporal width of the laser pulse passing the setup. The zero–dispersion is achieved when the properties of the output pulse are equal to the characteristics of the input pulse.

7. Place the SLM in the Fourier plane (in the back focal plane of the second lens, where the individual frequency components are focused to their minimum size). Since the height of the optical axis was already set at the step (2), only the position of the liquid crystal array must be carefully set so that the pulse spectrum passes through the center of the modulator. The spectrum can be observed by using a fiber optic spectrometer. Set two or three of the central pixels to zero amplitude (voltage off). The missing frequencies produce a ”hole” in the pulse spectrum. Move the modulator until the ”hole” is placed in the middle of the spectrum observed with the spectrometer. In this way the liquid crystal mask is centered on the optical axis.

8. The pulse shaper setup should be now free from spatial and temporal chirp.