Compact Multipass Yb: KGW Amplifier for Photocathode Laser Driver

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The RF photoinjector gun is currently under development at the Institute of Applied Physics of the Russian Academy of Sciences (IAP RAS) [1]. The photoinjector is supposed to deliver electron bunches with a charge of up to 100 pC and an FWHM length of 10 ps. The gun with a clean copper cathode is driven by a 5 MW RF klystron at 2.45 GHz and a dedicated UV laser. The laser system comprises the following parts: passively mode-locked Yb-doped fiber master oscillator (MO) with phase-lock loop; fiber front-end with multiple amplification stages and built-in spectral pulse shaper; solid-state diode-pumped multi-pass Yb:KGW amplifiers; grating compressor, and fourth harmonic generator. Given the quantum efficiency of the copper cathode around 3×10^{-5}, the required UV energy is 16 μJ per pulse; thus, the required IR energy would be 300 μJ per pulse with a certain margin.

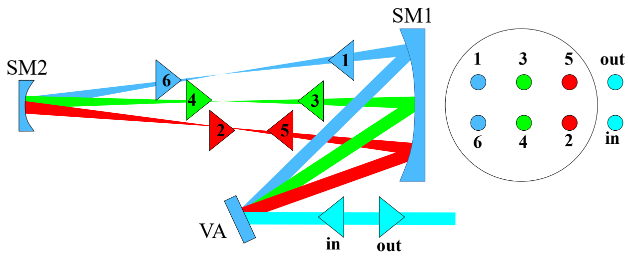

Figure 1: Multipass amplifier layout

In this work, we present the development and characterization of the multipass amplifiers as part of the photoinjector laser setup. We employed a 3% doped Yb:KGW crystal (Optogama) with the aperture of 7×7 mm^2 and 3 mm length. Its front surface was anti-reflection coated for pump and signal at 940 and 1030 nm, respectively, while the backside was highly reflective for both, i.e. the pump and the signal enter and exit from the crystal from the same side, following the so-called V-pass trajectory. The crystal was cut along the crystal-optic N_g axis, with the N_m axis being parallel to the long side of the crystal. The polarization of both pump and signal beams was collinear to N_m in order to benefit from the highest gain cross-section. The multipass geometry of the amplifier was described in detail in [2] and is shown in figure 1, where VA is the Yb:KGW crystal and SM1,2 are the spherical mirrors. The pump beam is not shown in the figure; it makes a single V-pass in the plane orthogonal to the plane of the figure. We used a 360 W diode pump (BWT, China) stabilized at 940 nm and delivered through the multimode fiber with 200 μm core diameter (NA=0.22); therefore, the beam distribution was almost perfectly uniform at the fiber end. Special care was taken to ensure a high-quality, nearly aberration-free image relay of the fiber end to the crystal surface with a factor of 6 magnification. The uniform distribution of the pump beam on the crystal prevents detrimental signal beam spatial narrowing when it comes to the saturation level.

With this amplifier arrangement, we achieved a uniform pump beam distribution with an intensity up to 30 kW/cm2 at the crystal surface and the net gain of 120 for 13 V-passes for the 8 nm bandwidth low power seed signal centered at 1034 nm. At the same time, we observed a significant spectral blue shift in the signal beam. This observation is supported by the measured spectrum of Yb:KGW luminescence centered around 1023 nm for our pump intensity.

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References

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