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The output pulse energy from a single-aperture high-energy laser amplifier (e.g. fusion lasers such as NIF and LMJ) are critically limited by a number of factors including optical damage, which places an upper bound on the operating fluence; parasitic gain, which limits together with manufacturing costs the maximum aperture size to ~40-cm; and non-linear phase effects which limits the peak intensity. For 20-ns narrow band pulses down to transform-limited sub-picosecond pulses, these limiters combine to yield 10-kJ to 1-kJ maximum pulse energies with up-to petawatt peak power. For example, the Advanced Radiographic Capability (ARC) project at NIF is designed to provide kilo-Joule pulses from 0.75-ps to 50-ps, with peak focused intensity above 10^{19} W/cm^2. Using such a high-energy petawatt (HEPW) beamline as a modular unit, we will discuss large-scale architectures for coherently combining multiple HEPW pulses from independent apertures, called CAPE (Coherent Addition of Pulses for Energy), to significantly increase the peak achievable focused intensity.

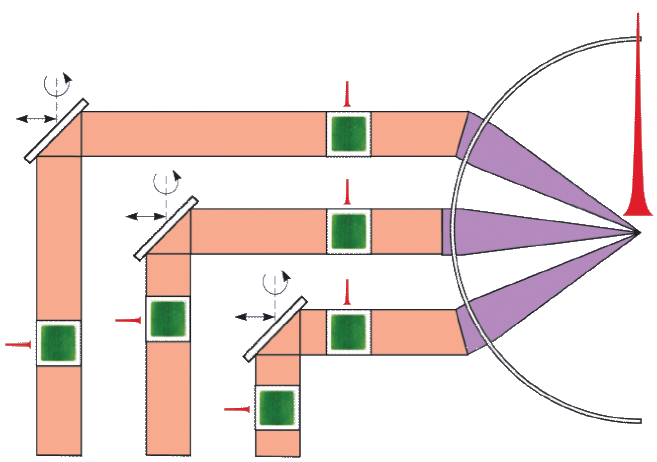

Figure 1: The CAPE geometry. Pulses output from independent amplifiers (with a common seed) are rephased to coherently add in their common focal plane. The peak intensity scales quadratically with the number of apertures.

Importantly, the maximum intensity achievable with CAPE increases non-linearly. Clearly, the total integrated energy grows linearly with the number of apertures N used. However, as CAPE combines beams in the focal plane by increasing

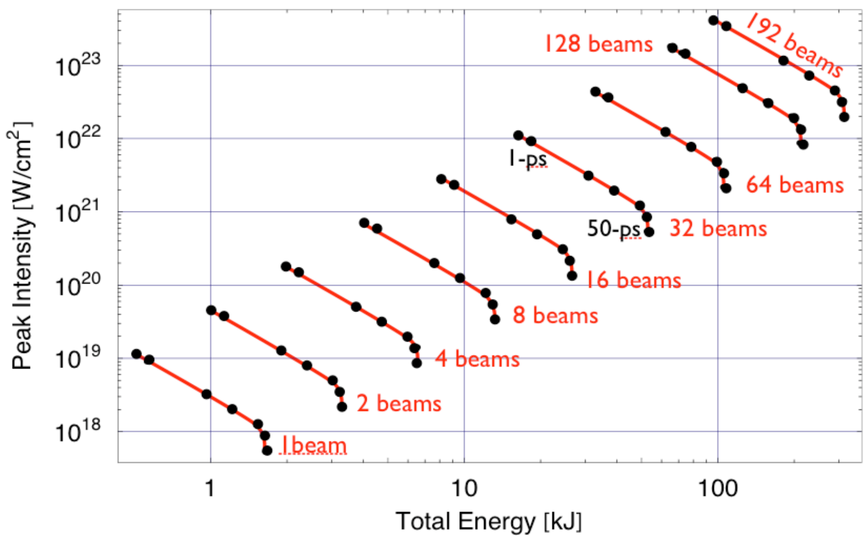

Figure 2: Scaling of peak intensity achievable using CAPE on NIF ARC beamlines as a function of total energy. For each aperture set shown (1, 2, 4, 8, etc.), the peak intensity is shown in red for pulse durations from 50-ps down to the transform limit (approximately 0.75-ps).

the angular convergence to focus (i.e. the f-number decreases, see Fig. 1), the focal spot diameter scales inversely with N. Hence the peak intensity scales as N^2.

Using design estimates for the focal spot size and output pulse energy (limited by damage fluence on the final compressor gratings) versus compressed pulse duration in the ARC system, Figure 2 shows the scaled focal spot intensity and total energy for various CAPE configurations from 1, 2, 4, …, up to 192 total beams. We see from the figure that the peak intensity for even modest 8 to 16 beam combinations reaches the 10^{21} to 10^{22} W/cm^2 regime. With greater number of apertures, or with improvements to the focusability of the individual beams, the maximum peak intensity can be increased further to ~10^{24} W/cm^2.

Lastly, an important feature of the CAPE architecture is the ability to coherently combine beams to produce complex spatio-temporal intensity distributions for laser-based accelerators (e.g. all-optical electron injection and acceleration) and high energy density science applications such as fast ignition.

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