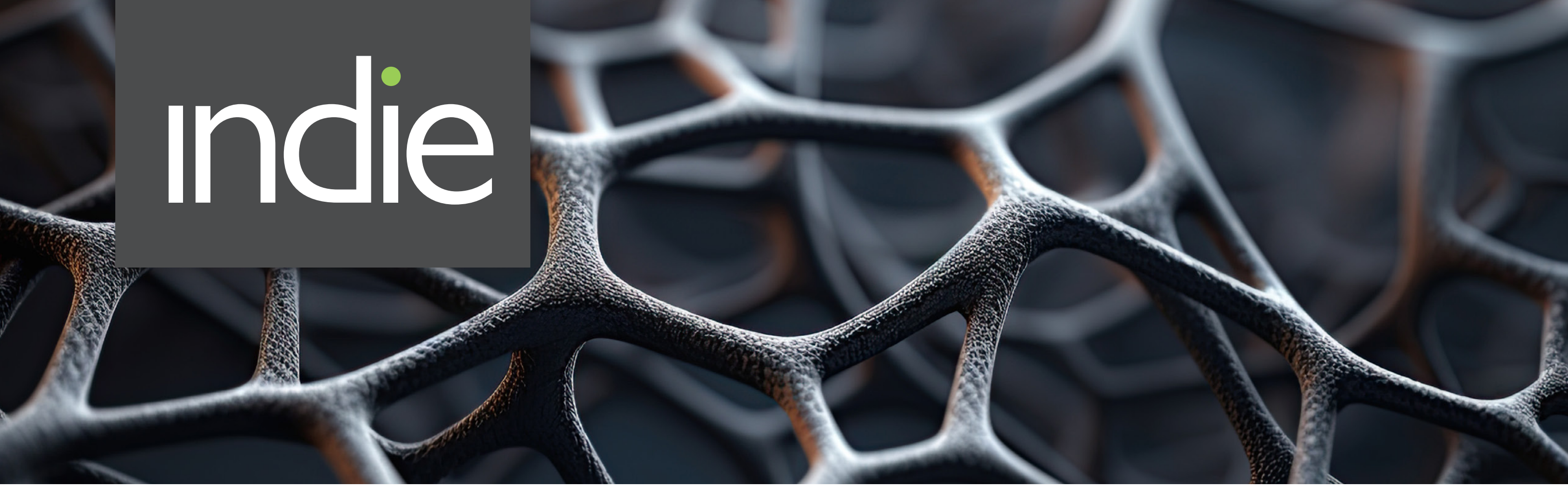

Effective Mitigation of Gain Narrowing in CPA-Based Lasers Using Tailored Fiber Stretchers

Steeves Roy, Product Line Manager – Ultrafast Laser Components, indie

Gain narrowing is a well-known limitation for designers of ultrashort pulse laser systems. Discover a clever way to counteract it and obtain shorter pulses with higher energy.

Introduction

Today many industrial, medical, and scientific applications benefit from the advantages provided by short-pulse lasers. Various physical effects must be controlled by laser designers to prevent the pulse duration from lengthening beyond the requirements of laser processes. Gain narrowing is one of these mechanisms that must be countered, here we will put an emphasis on CPA (Chirped Pulse Amplification) laser systems.

What Is Gain Narrowing?

Gain narrowing is the phenomenon in which the bandwidth of light is reduced during amplification in a medium with a limited gain bandwidth. This is caused by the center region of the optical spectrum experiencing a higher gain than the spectral wings. As the amplification increases, the pulse spectrum also tends to shift towards the peak of the gain curve, as illustrated in Figure 1.

Gain narrowing affects the pulse duration and stability of ultrashort pulses in ultrafast lasers and amplifiers. Without any means of mitigating gain narrowing at wavelengths around 1 µm, it becomes extremely difficult, if not impossible, to obtain high energy pulses shorter than ~ 700 fs with solid-state amplifiers and less than ~ 200 fs with Yb fiber amplifiers.

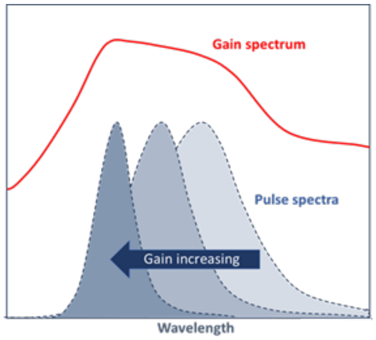

Figure 1: Illustration of the impact of gain narrowing

Mitigation of Gain Narrowing

Different strategies can be implemented to minimize the impact of gain narrowing, for example:

- Reducing the insertion loss, as the incidence of gain narrowing increases with the gain of the amplifiers,
- Using gain-managed nonlinear fiber amplifiers,
- Use of an optical filter to introduce losses in spectral regions where the gain is higher (gain equalization).

We discuss the latter approach below in the context of CPA laser systems with fiber-based front-end.

Tailored Fiber Pulse Stretchers

The use of pulse stretchers based on Chirped Fiber Bragg Gratings (CFBG) has become widespread thanks to their compactness, reliability, and configurability. A typical implementation diagram is shown in Figure 2. indie's line of fixed (PSR) and tunable (TPSR) pulse stretchers is the most comprehensive and versatile on the market. Dispersion and reflectivity can be tailored to suit a wide range of laser architectures relying on fiber and/or solid-sate amplifiers.

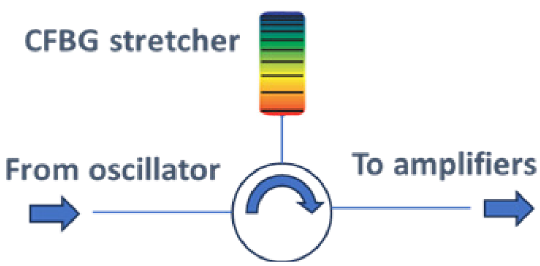

Figure 2: Typical fiber pulse stretcher configuration

An elegant way of counteracting gain narrowing using the principle of gain equalization without adding any components is to design the stretcher with lower reflectivity at wavelengths where gain is maximum, as illustrated in Figure 3. This option of indie stretchers has proved useful in the industry, notably by enabling pulse duration well below 500 fs in high-energy fiber and solid-state hybrid laser systems.

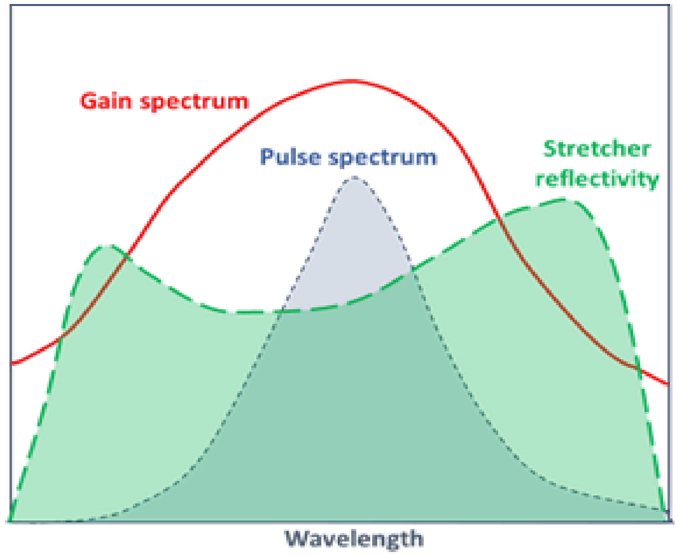

Figure 3: Conceptual representation of pulse stretcher with gain narrowing compensation option

Conclusion

Gain narrowing is one of the ultrafast lasers limitations that can be managed by cleverly designing fiber pulse stretchers. indie's cutting edge, cost-effective PulseStretch and TuneStretch can have the stretcher's reflectivity spectrum tailored to compensate for the non-uniform gain spectrum and obtain shorter pulses with higher energy.