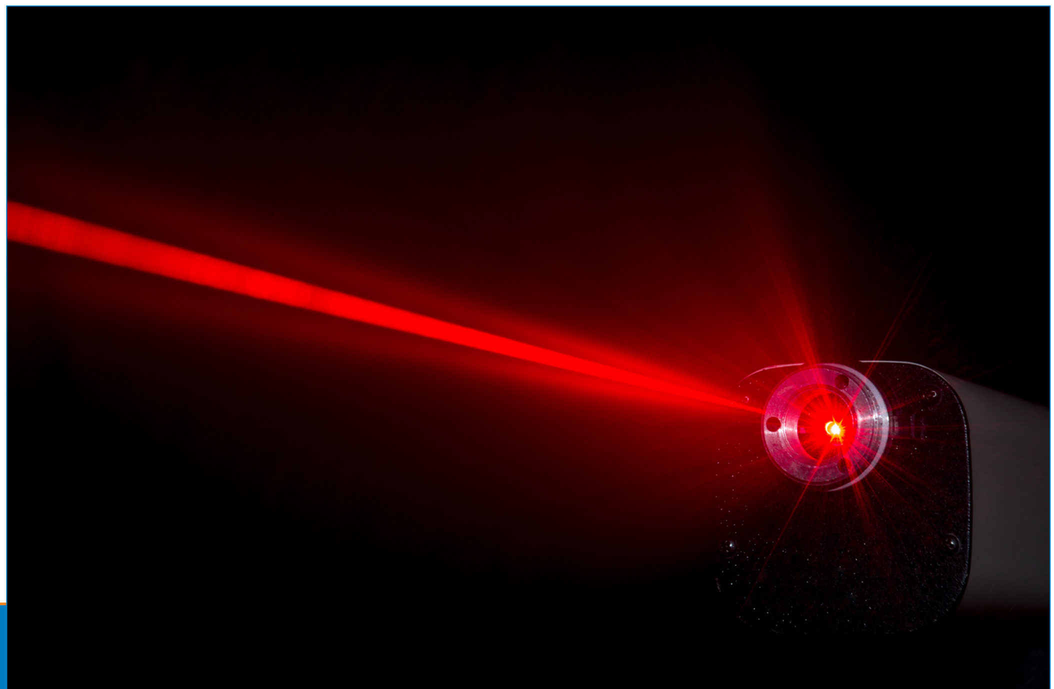
Application Note

Using a Noise Source for Improving Reliability and Performance of Directed Energy Weapons



Abstract

Directed energy weapons (DEW) using highly focused energy of lasers are powerful weapons that can destroy long range targets with pinpoint accuracy. These weapons bring significant advantages to traditional weaponry along with unique design and deployment challenges. The high optical power required for an effective DEW drives potentially high return loss and reflection that can damage laser sources. Use of a radio frequency noise source embedded in the weapon's electronics can spread laser coherence, minimize reflection, and protect the laser source.

Directed Energy Weapons

Directed energy weapons (DEW) are designed to neutralize a target using highly focused energy, such as lasers and microwaves. High-powered microwave weapons, for example, propagate in a cone shape and prove effective in disabling short-range drone swarms with microwave jamming, which deliberately disrupts a drone's wireless communications using broadband noise sources. Laser weapons, on the other hand, are powerful point weapons that can destroy long-range targets with pinpoint accuracy.

DEW offer a series of advantages compared to traditional weaponry to counter rising security threats across all domains. DEW can provide an endless magazine if enough power is available, thus eliminating the logistical problems of finite ammunition supplies and lowering the total cost per shot. Its speed-of-light delivery can neutralize long-range targets while significantly reducing collateral damage. In addition, DEW offer a wide range of platform flexibility, capable of launching from large vehicles; ships at sea; fixed, land-based structures; and airborne platforms, among others.

Due to a DEW's ability to provide a unique response to rapidly emerging global threats, many industries and military branches are channeling research and development (R&D) efforts toward directed-energy technologies poised for near-term deployment. However, certain design issues must be addressed in order to achieve the high-power levels necessary to support laser-based DEW deployment in critical security operations.

To reach the high optical powers of laser-based DEW, multiple laser modules are combined into a single beam. Increasing the power per module can increase the total output of the system to necessary power levels, however, the high optical intensity of each module over the fiber can generate Stimulated Brillouin Scattering (SBS) issues. Ultimately, SBS leads to a high return loss and can consequently damage the laser source. Noisecom noise generators and sources can address the critical needs of SBS reduction by driving coherence spreading to minimize retroflected scattering, allowing for high optical power transmission.

What Is Stimulated Brillouin Scattering?

Brillouin Scattering is a nonlinear process in optical fibers that involves the interaction of an incident light wave (pump wave) with acoustic phonons in a medium. During this process, parts of the incident light wave are converted into acoustic phonons, as well as a scattered light wave of slightly lower energy in the backward direction. The backward reflected light beam is referred to as a Stokes wave.

Brillouin Scattering can occur spontaneously, however, intense beams of light traveling along an optical fiber (i.e. directed energy laser systems) can lead to Stimulated Brillouin Scattering (SBS). SBS occurs when the light beam's own variations in its electric field considerably contribute to the medium's acoustic vibrations through electrostriction. Since laser systems achieve such high optical power, SBS can reflect a significant fraction of the incident light beam at high-power levels (See Figure 1). As a result, SBS leads to a high return loss and can potentially damage the laser source, which is an issue commonly faced when increasing the power per module in coherent laser system weaponry (See Figure 2).

SBS isn't a phenomenon unique to DEW, and has early roots in other areas, such as the telecommunications industry. SBS has been observed in wavelength-division multiplexing (WDM), which multiplexes a variety of optical carrier signals onto a single fiber, enabling bidirectional communication and an increase of capacity. Techniques to reduce SBS are highly sought after within optical communication systems utilizing WDM to enable high-speed data rates. Now, this proven methodology has transferred over to the military sector in order to facilitate SBS reduction in DEW.

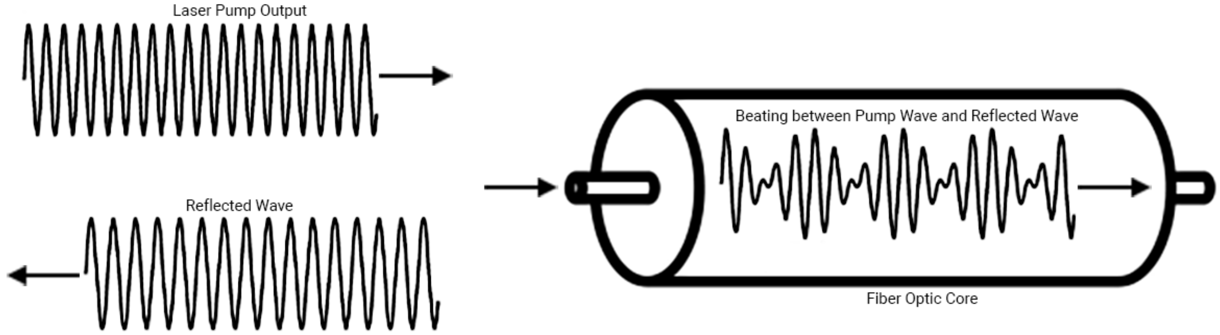


Figure 1 - Fiber Optic Core - Beating between pump wave and reflected wave caused by electrostriction.

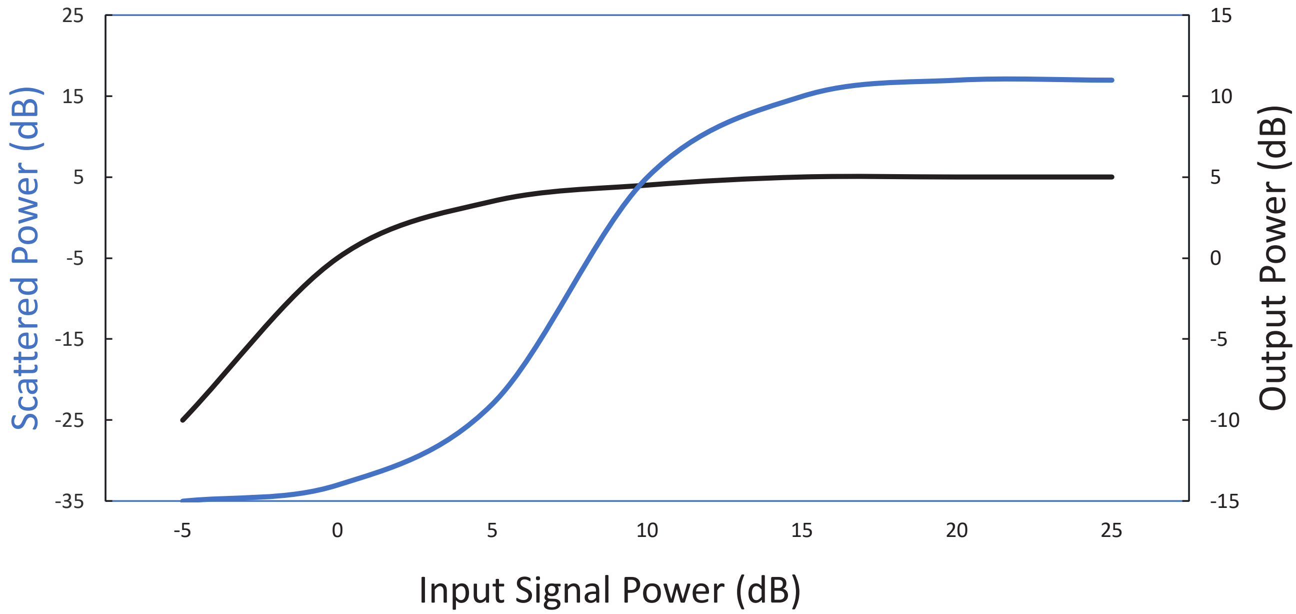


Figure 2 - As laser power increases SBS return loss also increases.

SBS Reduction through Coherence Spreading

To achieve high-power coherent laser systems, DEW designers strive to increase the system's power per module, however, each module's high peak power can result in SBS challenges. One way to mitigate SBS issues is to reduce the peak power by spreading the coherence of the laser. Although the peak power is reduced, the average power remains same, therefore the overall optical power of the laser is maintained (See Figure 3). As a result, DEW can achieve the same desired optical power while reducing the negative effects of SBS.

Coherence spreading can be achieved through modulating the phase of the laser. Using this technique, the phase of the optical wave is modified with a modulating signal, which can be created by a random noise source. The optical wave's peak amplitude and frequency remains constant, however, its phase (or the distance between the peaks) changes as the modulating signal's amplitude changes. Therefore, the peak power is effectively spread out throughout the waveform while maintaining the same average power of the system.

There are two generally accepted approaches to drive coherence spreading in a laser module. One option is to use a bit error rate generator, which injects a pseudorandom binary sequence (PRBS) as a coherence-spreading catalyst. Acting as a form of digital noise, a PRBS is a deterministic binary pattern of pulses that periodically repeats and satisfies statistical randomness. Although functional, these devices are expensive, large, exhibit instabilities when exposed to environmental conditions (temperature, vibration), and require the addition of complicated electronics to the laser module.

Alternatively, an additive white Guassian noise (AWGN) source offers a cost effective, easy to use, and environmentally robust coherence spreading methodology for high-power laser systems.

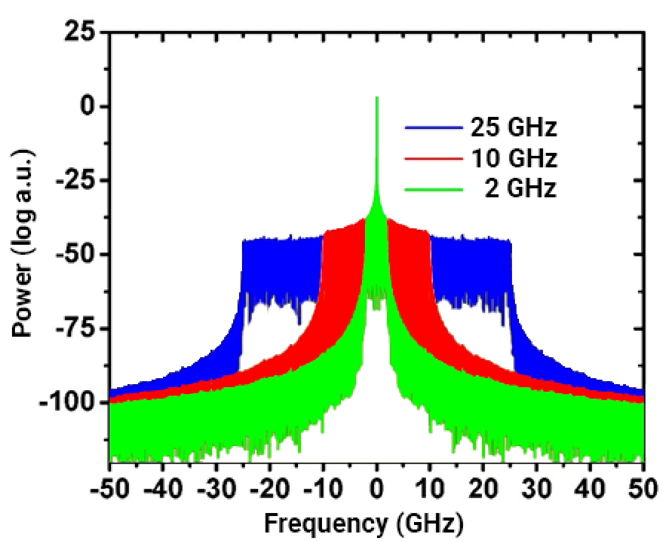


Figure 3 - The peak power of a signal is reduced while maintaining the same average power to achieve coherence spreading.

Driving Coherence Spreading with Additive White Gaussian Noise

An AWGN source can be directly injected in to the laser module to drive coherence spreading, providing a low cost technique to manage the impact of SBS. Noise generating components typically provide a fixed output power level, however, when combined with precision attenuators, filters, and amplifiers, they can become controllable devices with specific power levels and frequencies that are ideal for each laser system's unique coherence-spreading requirements (See Figure 4). Delivering superior flatness and repeatable output power, noise sources reliably provide a truly random signal, as opposed to a repeated pattern of pulses, to mitigate SBS within DEW systems, all while maintaining a low price point.

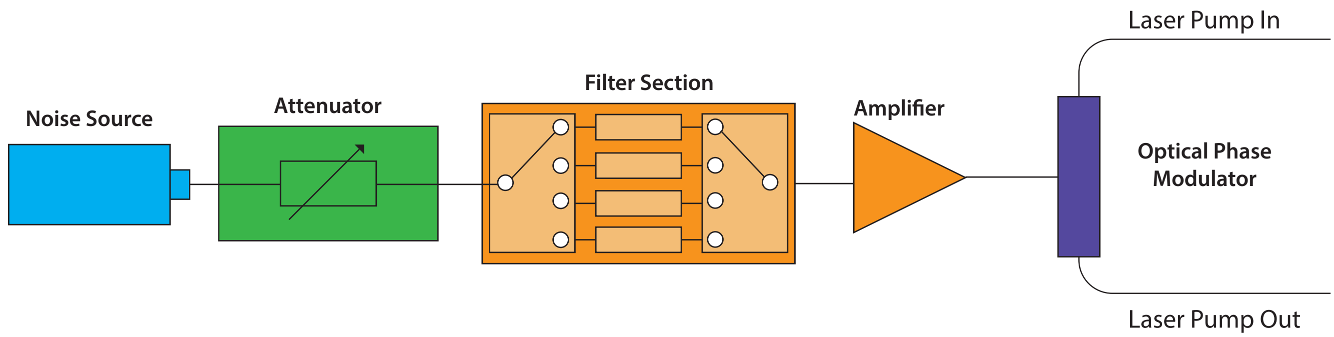


Figure 4 - A fixed output power level noise source connected to a laser module with a variable attenuator, switchable filter bank and amplifier used to drive coherence spreading in a DEW system.

Designing and Deploying DEW with a Noise Source

During development it is important for DEW designers to have full control of all aspects of their systems. A programmable noise generator provides the noise source required for mitigating against the impact of SBS along with a range of control capabilities. An instrument like the Noisecom UFX7000A has user-controllable attenuation, filtering, and amplification to generate the exact noise output for any laser system requirements. Highly customizable and configurable, the UFX7000A provides variable output power noise with a dynamic range of 127 dB in increments as small as 0.1 dB offering the highest level of noise control. The UFX7000A Series can be customized to also include up to five filter paths to change the video bandwidth and provide noise band limiting capabilities, which can help pinpoint the most appropriate bandwidth of noise for specific applications. Amplification of the signal is also available for up to +30 dBm.

Combining a noise source with variable attenuation, filtering, and amplification enables the UFX7000A to deliver a programmable, self-contained unit that can suit a variety of design needs. Due to the instrument's high level of versatility and control over noise power levels and frequencies, it is an ideal device for proof-of-concept DEW in the R&D stage to aid designers in determining system requirements and specifications.

To transition from the engineering lab to the later stages of production and ultimately deployment, a DEW system must embed a noise source with a compact form factor. The Noisecom NC1000 amplified noise module is a broadband noise source ideal for production-ready laser systems with finalized specifications due to its fixed power output. Producing AWGN up to +13 dBm, each module contains a hermetically packaged noise diode that has been pre-selected for special performance characteristics. The standard module is designed for a 50 Ω load impedance and has bandwidths from 10 MHz to 10 GHz.

For integration into a final DEW system, designers would use the NC1000 as a standalone noise source, adding system specific components like attenuators and amplifiers. Much like the UFX7000A, Noisecom offers a range of customization and integration capabilities for the NC1000, including the ability to incorporate specific attenuators and amplifiers alongside the noise source in a single package.

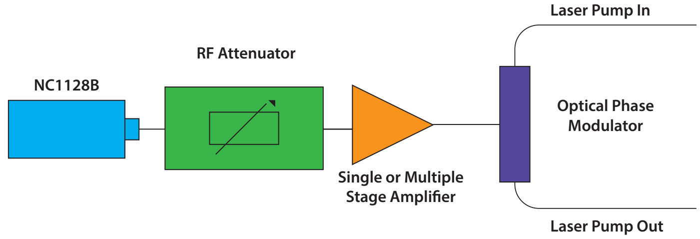


Figure 5 - Compact and cost-effective standalone noise sources like the NC1000 complement production-ready laser systems.