Fiber Optics

Coherent Beam Combining (CBC)

Combining Laser Beams to Gain Power

One of the architectures implemented for the construction of a high-power fiber laser is the possibility of combining different laser beams. Knowing that today a single fiber laser can deliver a power of the order of a kilowatt, or even ten kilowatts, the optical combination by phasing multiple sources results in a new laser delivering powers of up to several hundred kilowatts. There are several techniques for combining lasers. Among them, two require the use of phase modulators: the spectral combination of laser beams and the coherent combination of beams. For each of these architectures, iXblue Photonics has managed to develop a dedicated product (bandwidth, driving voltage, suppression of non-linear effects, etc…).

Coherent Combination of Laser Beams

A single laser source with a fine linewidth (on the order of kHz) is amplified several times and feeds an array of phase modulators (a phase modulator is placed on each laser beam path). Phase correction is applied individually for each beam. The modulator dynamically corrects the distortions of the optical paths and maintains the spatial and temporal properties of the output laser beam. In other words, the combination of several lasers by real time control of their relative phases allows to permanently maintain constructive interferences and thus guarantee maximum power efficiency during the combination.

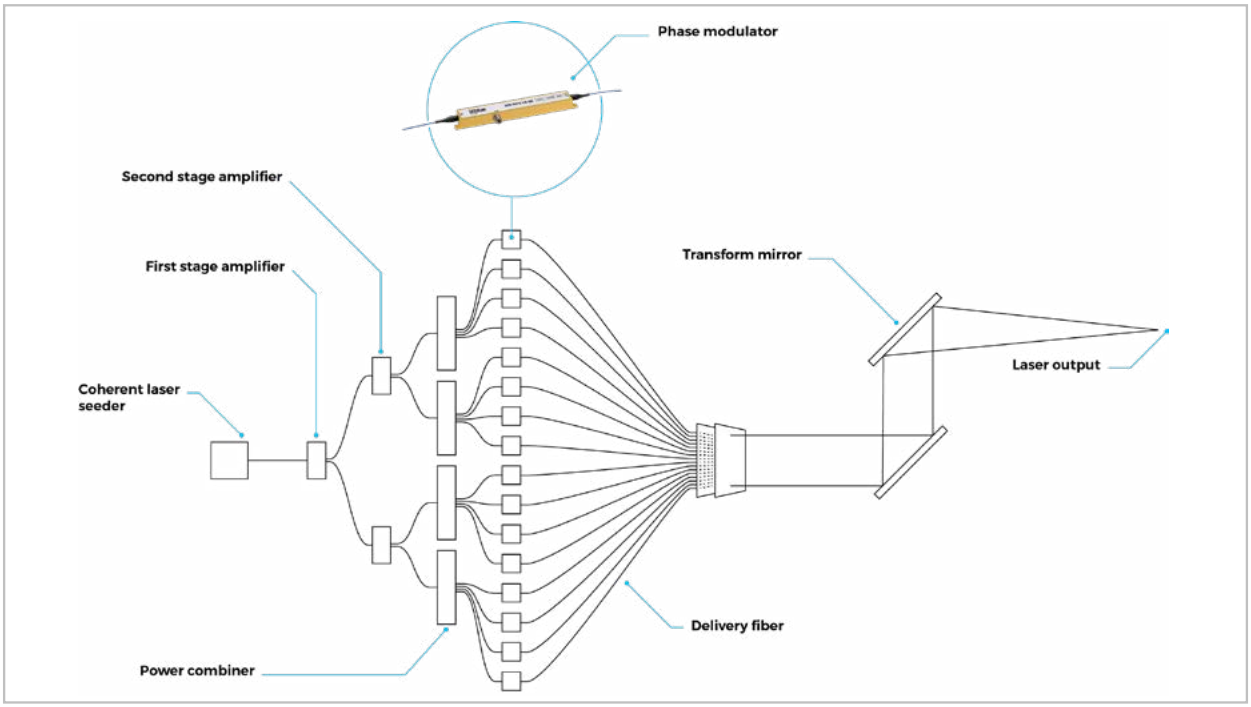

Fig. 1: A single laser source amplified several times and powers an array of phase modulators

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The phase correction of each beam is carried out in the low frequencies, on the order of kHz, using a DC coupled RF interface. This modulator must be insensitive to temperature variations and not induce any non-linear effects. Excellent polarization extinction ratio is beneficial in such configuration and calls for a polarizing waveguide. Low optical losses are also a benefit with the advantage of withstanding high optical powers to guarantee maximum power from the laser system.

NIR-MPX-LN-01 and its matching amplifier DR-VE-0.1-MO are both ideal for high-power coherent beam combining applications. The NIR-MPX-LN-0.1 is also produced using the APE process. The resulting polarizing waveguide can produce a polarisation extinction ratio value greater than 60 dB at the output of the optical waveguide chip. The APE process also helps to achieve a high optical input power handling of 300 mW. This modulator also features low insertion loss, and high optical stability.

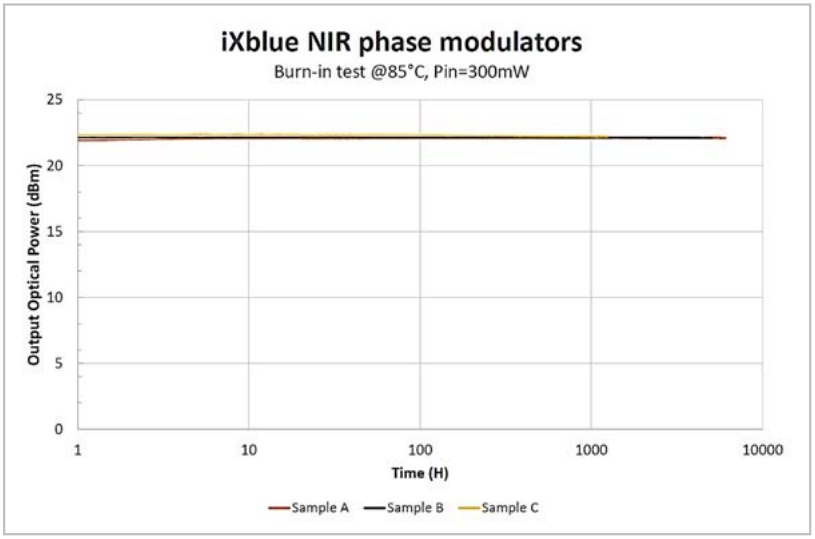

Fig. 2: Modulator NIR-MPX-LN-0.1 stability versus optical input power

The modulator is also a DC-coupled device. It means that you can apply a DC voltage to minimize the Residual Amplitude Modulation (RAM) effect (iXblue Photonics patented technique, US2016109734A1, "Electro-optical phase modulator and modulation method"). The graph below displays measured RAM values with applied DC voltage. It shows that it is possible, by simply adding a DC component, to reduce Residual Amplitude Modulation by a factor ten or more.

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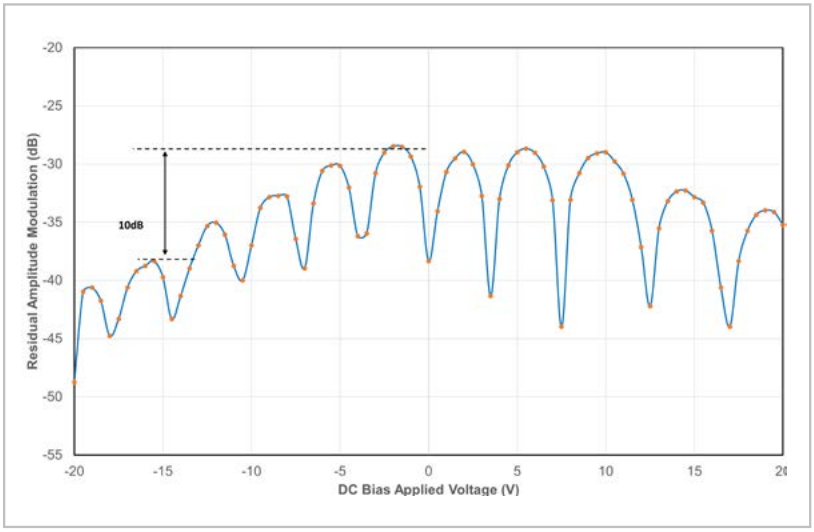
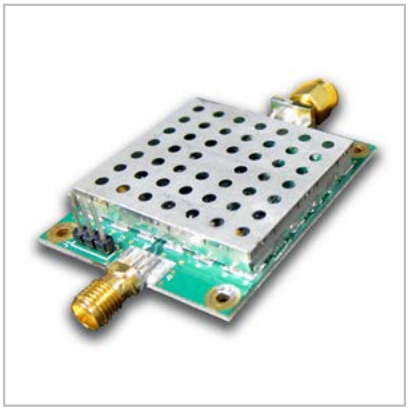


Fig. 3: Residual Amplitude Modulation modulator response

TN-RAM Effect and Mitigation Technic

Electro-optic bandwidth	DC coupled to 200 MHz
Vπ @ 2 GHz	1.5 V
Input optical power	up to 300 mW
Input electrical power	up to 33 dBm
Bandwidth	DC coupled to 200 MHz
Gain	26 dB
Saturated out	20 V_{pp}



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iXblue Photonics' product line is complemented by the ModBox-CBC-1064 nm. This optimised rackmount solution is a proven and robust multi-channels phase modulation solution for multibeam coherent combination. The ModBox operates at 1064 nm and integrates 2 to 8 independent channels with phase and delay tuning capability. Each channel allows an adjustment of the temporal phase for synchronization of all beams. The design integrates iXblue Photonics proprietary low frequency phase modulator with its matching RF electronic and a tunable optical delay line that is selected for high accuracy and a wide delay adjustment range.

Special care is taken for the assembly of the ModBox: the iXblue electro-optical phase modulators are screened from our regular production to ensure very low insertion loss, high polarization extinction ratio, low residual amplitude modulation, and high phase modulation stability. Additionally, iXblue Photonics phase modulator is well known to be the best planar phase modulator in the NIR featuring the highest optical input power handling capability. The component selection makes ModBox-CBC-1064 nm an accurate, adjustable, and reliable phase-lock modulation solution for Coherent Beam Combining technique.

Channel	1xNIR-MPX-LN-0.1 + 1x DR-VE-0.1-MO + 1xTunable-ODL
Operating wavelength	950 nm – 1150 nm
Insertion loss per channel	4 dB
Polarization extinction ratio	> 25 dB
Adjustable delay range	up to 600 ps

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