iXnews

IXBLUE | JANUARY 2018 | PHOTONICS WEST SPECIAL ISSUE

SPACE COMMUNICATION
iXblue's new active fibers

FIBER LASERS
Focus on NIR modulators and EY fibers

CURRENT AND STRAIN SENSORS
How do they work?

PRODUCT NEWS
Discover iXblue Photonics' latest products

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iXblue PHOTONICS

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PRODUCTS STORIES

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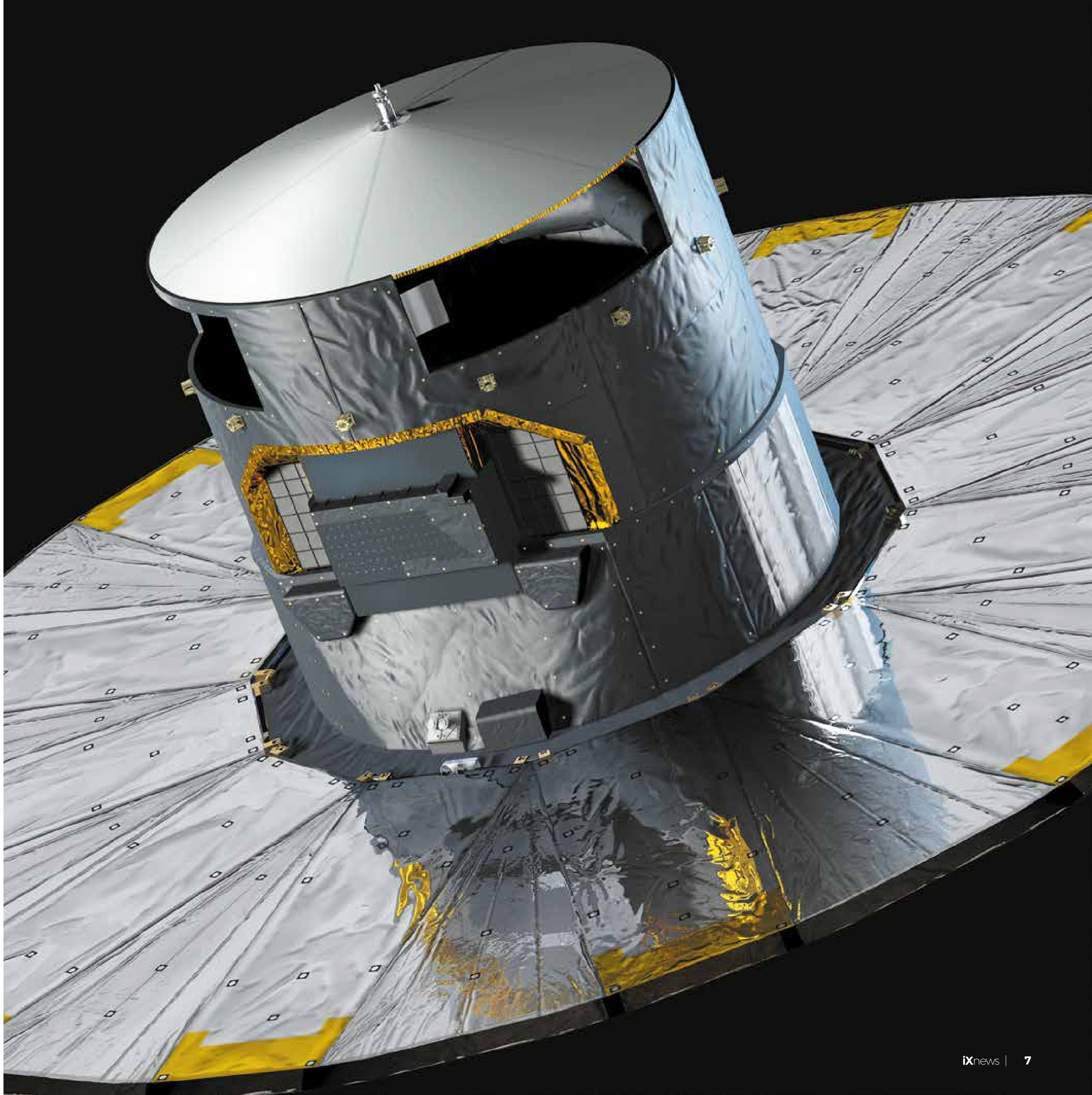
FIBER OPTICS BY IXBLUE PHOTONICS SUPPORTING EUROPEAN SPACE RESEARCH

Since 2008, Lannion's research and development team has been working closely with the CNES (French Space Agency) on various research projects aimed at developing ever more robust and efficient fibers and amplifiers, in preparation for the future Universe exploration programs. Space is a particularly extreme environment, where technical constraints are high; the reliability of instruments is therefore paramount.

In 2016, the CNES took the decision to shift up a gear with the FAST10 project. The agency intends to negotiate a new technological step with the aid of iXblue Photonics' unique know-how. The objective is to develop a demonstrator of a spatial fiber optic amplifier with a 10 watt power rating, which will ultimately be capable of operational service under vacuum for periods of at least 10 years.

This very high performance system will inter alia make optical telecommunications possible between satellites and enable them to communicate with Earth. This major milestone is now feasible thanks to the development of new active fibers carried out under previous projects.

Thierry Robin, Arnaud Laurent, and Emmanuel Pinsard, explain the challenges of this program and look back with us on the cooperation and trust established over the years with the CNES.



"The reliability of the instruments developed is paramount. The qualification process is iterative and strict, and hence often long and costly. As a consequence, developments are conducted in stages according to successive technology readiness levels and the overall process can take more than 10 years."

When did cooperation with the CNES start?
The collaboration began at the end of 2007, shortly after the creation of iXfiber, when iXspace was looking to qualify a new polarization-maintaining fiber for the space business. Following this initial contact, we rapidly moved on to Research & Technology studies, working in particular on the hardening of Erbium-doped active fibers as well as other ancillary areas such as single-frequency DFB1 type fiber lasers.

What was the origin of the collaboration? Why did the CNES turn to iXblue in particular?
The CNES seeks French industrial partners that can help the agency gain in maturity on key systems or components and promote the development of French technology and know-how in instrumentation, in preparation for the future Universe exploration and research programs. From its inception, iXfiber forged partnerships with the French Alternative Energies and Atomic Energy Commission (Commissariat à l'énergie atomique et aux énergies alternatives – CEA) to study the darkening of fibers in the space environment. Numerous collaborations already existed between the CNES and the CEA. The fact that iXfiber wanted to work with the CEA on an "open-book" basis on the mechanisms of darkening in fibers, unlike some of our optical fiber manufacturing competitors, was a very positive factor for CNES. This collaborative work was subsequently extremely fruitful, particularly in terms of intellectual co-ownership between iXfiber and CNES.

Why is the space environment so demanding?
Space is a hostile realm fraught with many technical constraints. The maintenance of systems in-flight has to be conducted in situ and is only possible using robust software to remotely control and calibrate instruments throughout the duration of a mission. The systems have to meet very stringent requirements (small footprint, lightweight) while delivering highly optimized electro-optical yields.

More precisely, what are the specific constraints that optical systems are subjected to in the space environment?
Firstly, there are the constraints encountered by the satellite during the launch phase, these are mainly mechanical and thermal stresses induced by the launcher or during stationing.
Then there are the constraints which the satellite undergoes once in orbit, and which are intrinsic to its operating environment. Importantly, in flight, the system must operate in so-called "severe" environments where climatic-thermal constraints (related to the space vacuum) and radiative constraints coexist.
In orbit, the vacuum causes degassing of materials at the beginning of their life cycle. These release molecules which may have been absorbed during their manufacture and this is liable to impact the operation of microelectronic or optical components. Moreover, the thermal stresses are very significant: even if the satellites use conductive devices to collect heat and evacuate it to the surfaces, heat exchanges with the space environment can only be radiative, resulting in two to three times lesser efficiency than in conditions of natural cooling on the ground.
With regard to radiative transfer, certain regions of space are made up of a "soup" of particles in perpetual interaction: cosmic rays, solar winds, the Van Allen belts.
A deterioration of microelectronic and optical components has been observed during space missions: in particular, optical fiber components are found to be among the most vulnerable, suffering significant loss of performance in the course of a mission. The appearance of color centers (a form of photon trap) creates absorption bands at wavelengths of interest, which will adversely affect amplification and transmission of signals. It is therefore essential to understand the phenomena responsible for this type of this premature aging and develop new optical fibers and systems based on these fibers permitting the longer periods of operation necessary for space missions. The reliability of the instruments developed is thus paramount. The qualification process is iterative and strict, and hence often long and costly. As a consequence, developments are conducted in stages according to successive technology readiness levels (TRL) and the overall process can take more than 10 years.

"The in-flight systems have to meet very stringent requirements while delivering highly optimized electro-optical yields."

What work have you undertaken with the CNES over the years?
Over time, the partnership with the CNES has come to focus on the development and optimization of so-called "active" optical fibers able to meet the constraints of optical amplification in a spatial environment.

What did the first research project consist of?
The first work we did was on resistance to radiation and the first hurdle we needed to cross was fairly clear - we had to find a solution for the hardening of the Erbium-doped amplifier fiber, compatible with communication in the C band (approximately 1.55 μm).
In 2009, we identified the key technological parameters, in other words the composition of the optical fiber and the manufacturing processes. Adopting a systematic approach, we conducted some twenty fiber designs to find the right compromise between fiber amplification efficiency and radiation hardening. To be able to do this comparative work, an optical bench

"Over time, the partnership with the CNES has come to focus on the development and optimization of so-called "active" optical fibers able to meet the constraints of optical amplification in a spatial environment."

was developed allowing us to simultaneously conduct amplified power measurements on 16 Erbium fibers under irradiation.
In this way, a technology patented in 2012 led to an improvement by a factor of 20 in the hardening of the Erbium fiber used in an optical amplifier delivering 10mW.
Outcomes included publication of numerous scientific papers enabling iXblue Photonics to gain recognition as a key specialty player in the eyes of amplifier manufacturers.

How did you follow up this first success with the CNES?

Rapidly, over the next two years (2013-2014), a need for higher amplified power levels emerged to meet the demands for increasingly rapid space telecommunications over ever-longer distances.
Architectures adopted in high-power optical amplifiers for the terrestrial environment are mature enough to be used as the benchmark. However, the space environment prevents the use of the same optical systems.
In order to support the high power operating mode, we optimized the composition of the amplifier fiber with co-doping associations combining Erbium and Ytterbium. The geometry has evolved and the fiber core has been doubled in size to avoid non-linear effects such as stimulated Brillouin amplification. Furthermore, the power outputs are so high that they cause heating of the doped fiber: the integration process has therefore been designed to meet the temperature regulation demands. The resulting additional constraints weigh in the energy balance of the amplifiers.

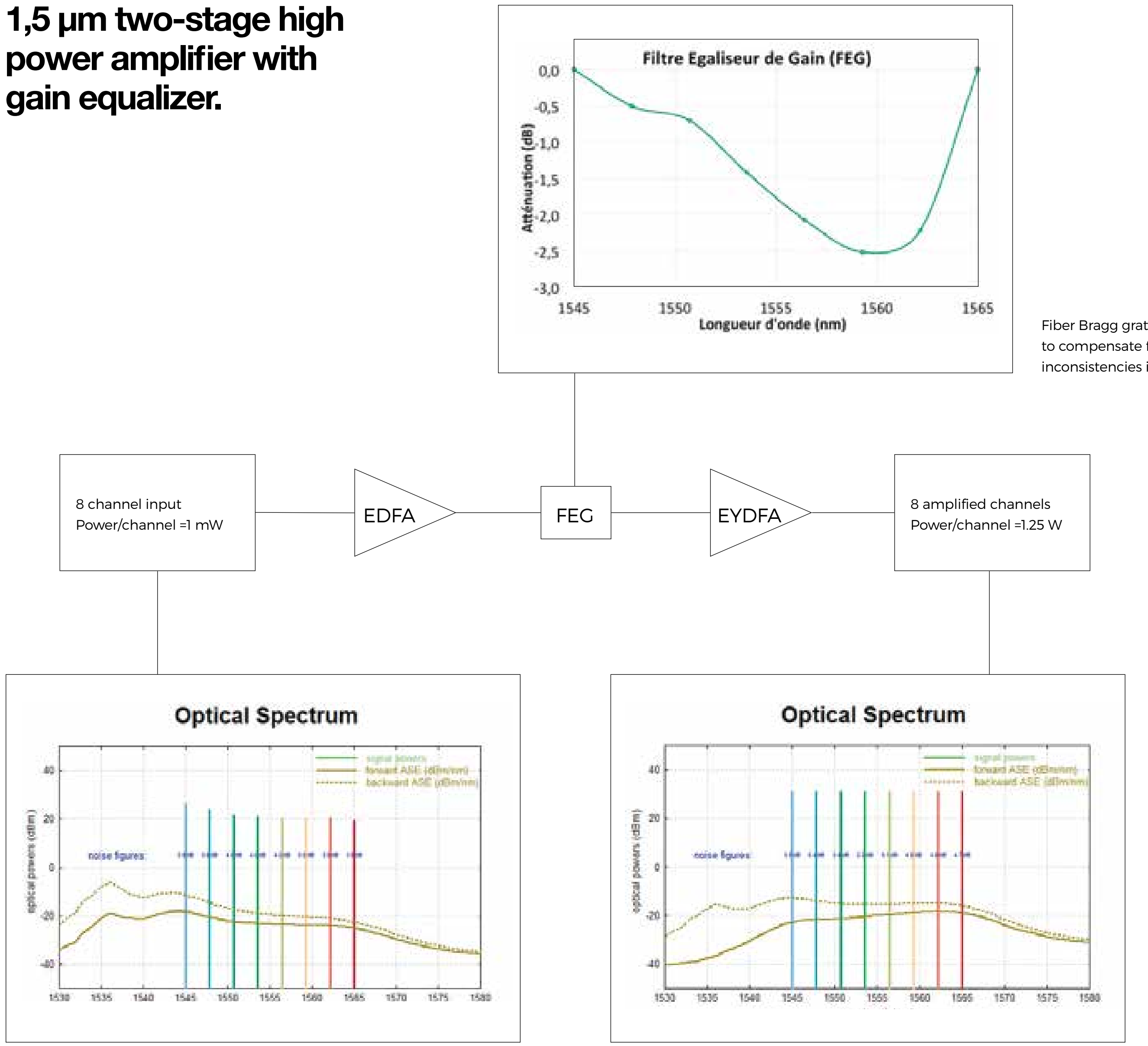
What project are you currently working on?

In the constant search for technological maturity, the CNES has this year ramped up its objectives on high-power laser sources, commissioning laser manufacturer CILAS to develop a demonstrator for a spatial 10 watt fiber amplifier, in close collaboration with iXblue Photonics. The aim therefore - within the framework of the FAST10 project - is to propose a demonstrator of the amplifier, the performances of which will be evaluated during environmental tests involving thermal and mechanical shocks, ionizing radiation and multiple endurance tests. Ultimately, the system will need to withstand in-service operation under vacuum for a period of 10 years and more. The spec goes beyond in-flight operation, because - as is often a requirement in the space industry - the system may have to accommodate a storage period of several years on the ground before launch.
If this capability is now possible, it is thanks to the emergence of new active fibers developed through previous R&T projects supported by the CNES, as well as to the development of predictive simulation software to anticipate the formation of defects in the fibers as a function of the cumulative dose levels received (thesis by Ayoub Ladaci - iXblue Photonics).
The development of 1.55 μm high-power multi-channel spatial optical amplifiers will enable satellites to communicate with each other and with the Earth (LEO[2] or even GEO[3]). The envisioned technological shift, i.e. the transition from RF[4] spatial communications to optical communications, is comparable to what we observed with the advent of optical fiber in terrestrial telecommunications, in other words a multiplication of effective bandwidth with rates per channel tens or even hundreds of times greater as well as the possibility of multiplying channels through wavelength division multiplexing.
If this technological breakthrough is confirmed, many projects should emerge. Some of these may call for a unification of skills between iXblue Photonics (Lannion and Besançon) and iXspace, opening the way for a convergence towards a global optical telecommunications solution for space, from the transmitter (with the modulation solutions of Besançon) through to amplification in both send and receive (with Lannion's fibers), and taking in iXspace's expertise in spatial components and systems integration with the Navigation Systems division.
It is thanks to all these technologies and areas of expertise that iXblue will be able to cross this technological milestone with a view to proposing the innovative telecommunications solutions which will prove decisive for future programs of observation of our planet. ■

[1] Distributed FeedBack
[2] Low Earth Orbit – Orbite terrestre basse
[3] Geostationary Earth Orbit – Orbite terrestre géostationnaire
[4] Radio-fréquence – Radio frequency

"In 2016, the CNES ramped up its objectives on high-power laser sources, commissioning laser manufacturer CILAS to develop a demonstrator for a spatial 10 watt fiber amplifier, in close collaboration with iXblue Photonics. Ultimately, the system will need to withstand in-service operation under vacuum for a period of 10 years and more."

Architecture of the 1,5 µm two-stage high power amplifier with gain equalizer.



Fiber Bragg grating to compensate for inconsistencies in gain

Pre-amplification of 8 channels by the EDFA

8 channels equalized at the EYDFA output (booster)

About CNES

From the early 1960s, France determined that space was to be a strategic priority and a cornerstone of national sovereignty. The French Space Agency (CNES - Centre National d'Études Spatiales) was created at the initiative of President Charles de Gaulle on December 19, 1961. With responsibility for coordinating and facilitating French space activities, the agency offers study programs in strategic fields such as Earth observation to understand its functioning, monitor its evolution and anticipate violent natural events. Its field of action also includes telecommunications where satellites play an essential role in high-speed communications, localization, environmental data collection, etc. In its collaborations with industry players, research and development efforts are mainly focused on innovation and competitiveness, with demonstrator programs targeting advances in technological maturity. CNES is today the largest national space agency in the European Union.

IXBLUE SPACE MODULATORS

CONTEXT

Photonics systems, sub-systems and components are found in an increasing number of applications of many high technology industry segments.
This remark applies particularly to space-embarked systems, which rely on the versatility and reliability of photonic systems to realize many of the critical functions needed to insure their safe and durable operation.
Many embarked space photonic systems use light modulators as a key component to achieve intensity or phase modulation of various light sources at different operating wavelengths: In particular, the electro-optic Lithium Niobate ($LiNbO_3$) modulators offer a unique combination of performance that makes them prime candidates, not only to satisfy the optical system specifications, but also to meet the tough requirements of space operation.

$LiNbO_3$ MODULATORS AND OTHER ELECTRO-OPTIC MODULATORS

The $LiNbO_3$ based modulator is one of the many optical modulators that have been developed in recent years. Initially, the development of these modulators was driven by the fiber optic telecommunication market that needed ever increasing modulation speeds. Today, E-O modulators are used in a large number of both telecom and non-telecom applications. The benefits and drawbacks of the main optical commercially available modulators clearly indicates that the $LiNbO_3$ E-O modulator offers the most attractive combination of performance, versatility and cost.
For space applications, the accumulated number of hours of operation and the proven reliability of $LiNbO_3$ modulators make them a very attractive choice compared with products issued from competing technologies. In addition, the $LiNbO_3$ modulators, beside their long standing proven record of use in many applications, and their many comprehensive successful qualifications (e.g., Telcordia) offer both a large optical bandwidth, ranging from 780 nm to 2500 nm, and a very broad electro-optic modulation bandwidth (> 40 GHz). Thanks to their unique combination of performance, $LiNbO_3$ modulators are used in very diverse space applications that include navigation, measure–countermeasure, telecommunications, sensing, etc…

APPLICATIONS OF $LiNbO_3$ MODULATORS IN SPACE

Laser Communication Terminal:
Free-space optical communication has been implemented between satellites since the 90's using directly modulated high power laser diodes at 820-850 nm. The emergence of fiber lasers in the near infrared and the availability of $LiNbO_3$ modulators in this band have made possible space optical links (LEO ⇔ GEO ⇔ Ground Stations) using more efficient modulation formats and offering improved data rates and BER.

Optical instruments for scientific missions:
Light can be used to measure many physical quantities, therefore one can see many scientific satellites with optical instruments on board. For instance, the GRACE missions measure variations in gravity over Earth's surface, producing a new map of the gravity field every 30 days. Thus, GRACE1 shows how the planet's gravity differs not only from one location to another, but also from one period of time to another.
The two GRACE-FO satellites will use the same kind of microwave ranging system as GRACE1, and so can expect to achieve a similar level of precision. But they will also test an experimental instrument using lasers instead of microwaves, which promises to make the measurement of their separation distance at least 20 times more accurate. Phase modulators are used to stabilize the laser cavities of the optical range finding system. The two satellites should to be launched in 2018.

MICROWAVE PHOTONIC PAYLOAD SUB-SYSTEMS (PROJECT)

Over the past few years, innovative payload concepts based on photonic technologies have been investigated by the manufacturers of communications satellites. Several architectures were elaborated covering different application cases including flexible analogue repeaters based on a photonic center section, and photonic receiver front-ends for advanced antennas allowing digital beam forming. Such architectures rely on photonic subsystems able to assist, complement, replace and/or extend the capabilities of conventional RF subsystems including:

- Optical generation/distribution of microwave Local Oscillators (LO)
- Photonic RF frequency up and down conversion
- Routing of μ-wave signals in repeaters
- Photonic assisted beam forming networks
- Optical sampling for analog to digital conversion

Optical modulators play a key role in the implementation of such functions. For instance, the optical distribution of LO's requires production of a microwave LO signal to be produced under optical form, with low phase noise and optical power high enough to be delivered to a large number of receivers while meeting system requirements. The transfer of a high-frequency signal onto an optical carrier through direct modulation of the laser current is not applicable at high frequencies, and requires external electro-optic intensity modulators. In particular, optical double sideband modulation with carrier suppression (DSB-CS) is an LO generation technique making use of a high-power CW laser and a MZ electro-optic modulator (EOM) biased at minimum optical transmission. When the modulator is driven by a microwave signal at $\varpi LO/2$ frequency, the optical output signal mainly contains the first two modulation side bands. Optical heterodyning at the photo receiver generates a microwave signal at the ϖLO frequency. Photonic RF frequency mixing for both up and down conversion of microwave signals can be achieved optically by means of EOMs.

Environmental tests to obtain the space qualification
To obtain their visa for space, beside the specific performance required for each application, external optical modulators have to pass a comprehensive environmental test program based on telecom TELCODIA and MIL reliability recommendations which includes radiation tests, vibrations and shocks, vacuum operation tests, thousand hours aging, damp heat operation tests, temperature cycling, ESD tests, hermeticity tests, outgassing analysis, and destructive physical analysis (DPA)…
iXblue received for that multiple support and research grant in the frame of programs from both ESA (European Space Agency) and the French agency CNES (Centre National d'Etudes Spatiales).

Modulators for space at IXblue
Over the past years, intensive design works and test programs have been conducted at iXblue to improve the environmental performance of the modulators and to make them compatible with space applications. The project are fully managed and documented (SOW, CDR, …) with respect to space standards.
In 2014, eight modulators were delivered to NASA: Two (2) of them are being integrated in the GRACE-FO tandem satellites and will fly in 2017, where they will join in space dozens of company modulators already operating in fiber gyroscopes. In 2014 as well, iXblue received a significant contract from TESAT-SPACECOM to design and deliver modulators for Laser Communication Terminals used for inter-satellite free-space communications.
New projects and new partnerships have been engaged since two years and are anticipating a wide deployment of modulator based photonic solutions in space. ■

INTERVIEW THIERRY ROBIN,
CTO iXblue Specialty Fibers division, on Erbium/Ytterbium doped optical fibers

About Thierry Robin

Thierry started his carrier as a research assistant at the Space Vacuum Epitaxy Center at the University of Houston, Texas, where he was involved in the development of a Laser ablation technique for thin film deposition of YBCO high temperature superconductors. He later joined Alcatel's optical fiber R&D group in 1992 where he held his first position in the Optical fiber business as an MCVD process specialist. Within the Alcatel group, Thierry held several positions in R&D, industrialization and production for both singlemode and multimode optical fibers. In 2000 he jumped onboard a then start-up, Highwave Optical Technologies, where he was in charge of the production and development of specialty optical fibers, such as rare-earth doped, double clad and polarization maintaining fiber.
In February 2006, he co-founded iXfiber, now known as the Photonic Solutions division of iXblue, where he serves as Chief Technology Officer. Overall, Thierry plowed his way continuously in the field of optical fiber for the past 25 years... and counting! Thierry studied Physics at the University of Houston. He authored or co-authored 7 patents and over 70 articles in scientific reviews and conferences.

How long has iXblue been involved in EY double clad fibers?

When iXfiber was created in 2006, most of the team had some experience with Erbium-Ytterbium co-doped double clad fibers. We rapidly identified that customers were looking for new EY fibers exhibiting high Power Conversion Efficiency (PCE), low 1 µm spurious emission and drawn with a high performance low index coating.
So we started almost from scratch and addressed these issues over the course of the past 11 years resulting in a complete line of high performance EY fibers today.

EY is well known for Optical fiber amplification for telecom and CATV applications, how do you see this market evolving?

Our development effort was initially driven by telecom applications. Both our 6 and 12 µm core diameter fibers have been optimized for CATV amplifiers with output power of a few Watts. PCE of 50% are routinely obtained in production for these fibers with extremely low 1 µm parasitic emission and tight absorption specifications, which enable high production yields for our customers. Some of our fibers are also optimized so as to obtain minimal tilt on the output spectrum. Historically, our main customers were European based laser manufacturers, some of these in close vicinity to our production site in Brittany, but in the past few years, we have experienced a fast growth of our sales worldwide and more specifically in China.

Any other active market?

Yes, the demand for Lidar sources for wind velocimetry for example and lately for autonomous vehicles has been pushing our development toward large core fibers up to 30 µm core diameter. For the latter market the 1.5 µm emission, being eye-safe clearly points towards EY sources.

The demand for high power CW sources has also been picking up; some of our customers building 1.5 µm sources in the 20-30W range. We have done extensive R&D to improve both the core composition and the low index coating package in order to bring this technology up to our customers' expectations. The main challenges concern photo-degradation within the very active core of the fiber and pump guidance degradation through deleterious low index coating degradation due to the high thermal load of these fibers. Even with an optimized PCE, 50% of the pump power will be absorbed by the fiber resulting in a large temperature increase that will have to be dealt with by a proper thermal management scheme.

What about Space Optical Communications?

We are pursuing our development in this area by financing our second PhD thesis in a row on the subject.
Over the past 7 years, we have developed a comprehensive product line of Erbium and EY double clad fibers. Our fibers can now be used in applications up to 10W in the space radiative environment suffering minimal power degradation. We do have Erbium doped fibers in space aboard more than 30 satellites and our EY radhard fibers are due to fly in the upcoming months.
Space grade fibers is clearly one of our preferred niche market... and the dog, as we see it, is getting bulky.

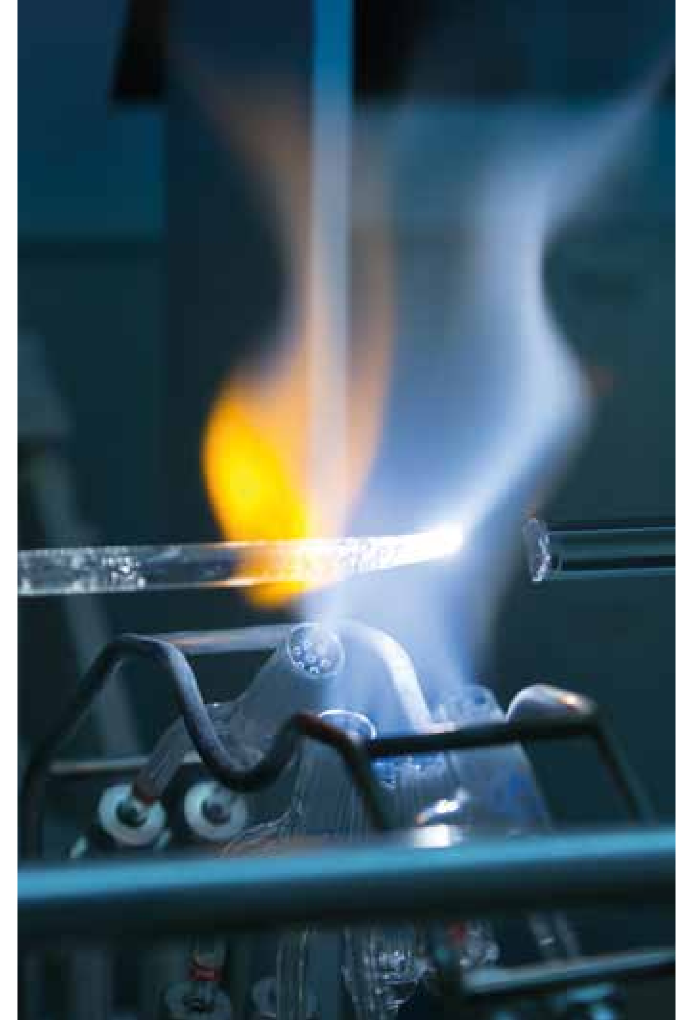
What would be the major strengths of iXblue?

We are an independent manufacturer of fiber and optical components and therefore not competing with our customers. Mastering both fiber and Bragg grating technologies gives us an edge for matched solutions.
We have long ago implemented a Manufacturing Execution System to manage our production and therefore have a complete control of the product manufacturing version with exhaustive traceability of both process and raw material. We also have a proven quality record with an extremely low non-conformity rate for shipped products. Most of our customers rank iXblue first in specialty fiber suppliers in our yearly quality assessment poll.

When it comes specifically to EY fibers, our customers especially appreciate first the high PCE obtained without sacrificing the 1 µm emission; internally, we are very proud of our coating package that exhibits excellent environmental performances.

After 11 years, do you still discover new things on EY fibers?

Surprisingly, yes. Pushing the fiber to its limits in terms of output power and core temperature unearthed hidden limitations rooted to the very chemistry of the active core.
One should remember as well that a specialty fiber can be 'special' from characteristics not limited to the core waveguide; in other words, we keep improving the fiber through coating enhancement for instance... So watch out for new EY fibers in the near future. ■



RAD HARD FIBERS FOR

NUCLEAR ENVIRONMENT AND HIGH ENERGY PHYSICS

For the past 10 years, iXblue has developed a large experience in the use of optical fibers in extreme conditions from undersea to space environment and in Oil & Gas, nuclear, medical, and aerospace applications.

Engaged in large scale R&D projects with the CNES (French Space Agency) and the CEA (French Nuclear Agency), iXblue Photonics has built a unique knowledge in radiation resistant fibers, both for passive and active doped fibers. From design to qualification, iXblue engineers will provide you with custom fibers specifically fitting your application with minimal RIA (Radiation Induced Attenuation) level.

Domains:
Nuclear Environment
High Energy Labs (Plasma diagnostic)
High Temperature

Examples of fibers:

Multimode Fiber for temperature sensing in nuclear environment

Graded Index Profile		Geometrical Specifications	
Core Composition: Fluorine dope silica		Core Diameter (µm)	50
Operational Wavelength (nm)	1064	Fiber Diameter (µm)	125
Attenuation (dB/km)	< 5	Numerical Aperture	0,12

Singlemode Fiber for sensing/data transmission in nuclear environment

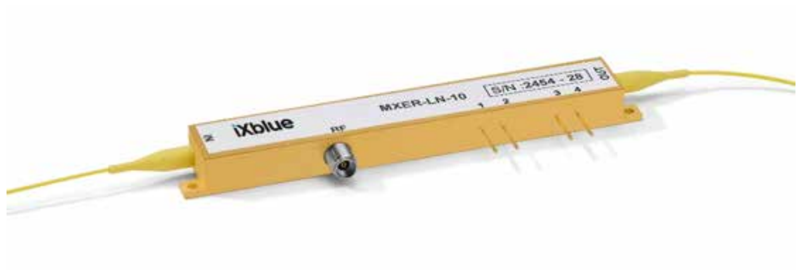
Step Index Profile		Geometrical Specifications	
Core Composition: pure silica		Core Diameter (µm)	7
Operational Wavelength (nm)	1310 / 1550	Fiber Diameter (µm)	125
Attenuation (dB/km)	< 1	Numerical Aperture	0,14

UV grade Multimode Fiber for High Energy Physics (Plasma Diagnostic)

Graded Index Profile		Geometrical Specifications	
Core Composition: Fluorine dope silica		Core Diameter (µm)	250
Operational Wavelength (nm)	351	Fiber Diameter (µm)	300
Attenuation (dB/m)	< 0,15	Numerical Aperture	0,12
Dispersion (ps/m)	< 1	Other Geometry available: 105/125, 400/450 µm	

Coating available:
Acrylate, Silicone, High temperature Acrylate,
Polyimide with optional carbon layer for Hydrogen protection

OPTICAL MODULATORS IN DISTRIBUTED FIBER SENSORS



iXblue Photonics offers a family of optical modulators specifically designed for the distributed sensor market based on BOTDA technology. BOTDA (Brillouin Optical Time Domain Analysis) relates to distributed sensors of temperature and strain in fiber cables installed along civil engineering structures (bridges, dam) and more particularly along pipelines. In the latter, this technology is particularly appropriate since it allows controlling the integrity of the pipelines on several tens of kilometers (>50 km) with a longitudinal spatial resolution better than one meter. This corresponds to typically 50000 points of measurement distributed between each station of data acquisition. The major interest is the detection of breaks, a leakage - even a weak one - of oil or gas will indeed be showing a modification of the external temperature. This can be obtained with a high precision positioning.
Such a monitoring system shows a particular interest in seismic regions and in subsea applications. By shortening the reaction time, it allows to prevent or reduce the risks of major environmental disasters and their resulting economic impact. Another major application of such a system concerns the subsea cables for the transportation of electric current produced by offshore wind farms.

The sensor is based on the use of the Brillouin effect in a silica optical fiber. When propagating an intense laser pulse, called «pump», in an optical fiber, a backscattering light is produced by optical nonlinearities. This Brillouin backscattering shows, at room temperature, an optical gain band with a frequency shift of 11 GHz compared to the optical carrier frequency (193 THz at the 1530 nm telecom wavelength). This frequency shift varies with temperature and strain. Its measurement allows to accurately identify these parameters at any position along the fiber where the Brillouin gain has been generated by the «pump». To get this, one launches another light wave in the fiber, in the opposite direction of the pump. This light wave, modulated by an RF sinusoidal signal, is called «probe». The frequency modulation of the «probe» is scanned around 11 GHz. When the «pump» and the «probe» cross each other at a given position in the fiber, the «probe» can be amplified by the Brillouin gain when the scanned frequency and the frequency shift are equal. The measurement of the frequency shift is obtained at reception depending on arrival time. It provides the accurate values of the parameters all along the cable.

iXblue is a supplier of those operation optical modulators (MXER) working at the 1530 nm infra-red wavelength. They are designed to be integrated into such sensor instruments. These modulators, based on Mach-Zehnder lithium niobate technology, can have two functions in the core of the instrument. They can generate the initial optical pulse of the pump, and they can generate the dual side band modulation with carrier suppression (CS-DSB) of the probe. These modulators show a broad bandwidth being dedicated to work at the 11 GHz frequency range. They show low insertion loss thanks to a specific waveguide design (patented by iXblue). Moreover, they guarantee a very high extinction ratio (>40 dB and beyond) without equivalent among existing competitors, the extinction ratio being a key parameter for the sensor spatial resolution along the fiber. The titanium technology used for the optical waveguides fabrication ensures a high and long-term stability of the modulator bias drift. It has to be noticed that iXblue also supplies fiber Bragg grating (FBG) filter that can be integrated in the sensor instrument. ■

INTERVIEW NICOLAS GROSSARD,

Product Line Manager Modulator, on near-infrared modulators made by iXblue

Nicolas Grossard (NGR) is the Product Line Manager for electro-optic modulators at iXblue Photonics. Dr. Grossard earned his PhD in Electrical Engineering from the University of Franche-Comté, France in 2001. He joined Photline Technology (now iXblue) in 2000 working in the development of low loss lithium niobate modulators. He currently holds 4 patents and has authored and co-authored more than 40 publications in journals and conferences.

Yves Deiss (YD) is a US distributor, and has over 15 years of experience on $LiNbO_3$. Yves Deiss had the opportunity to ask Dr Grossard some questions about the topic of the near-infrared modulators. He is Photonix Edge LLC CEO and founder, and has more than 17 years of experience in the business of optical fiber technologies. Prior to founding Photonix Edge LLC., Yves Deiss was general manager for US operations at Keopsys. Yves Deiss has an extensive technical background in photonics devices and components: acousto-optic and electro-optic modulators, optical fibers, as well as optical fiber amplifiers, lasers and modulation solutions such as ModBoxes.

YD: In a few words, can you tell us about the main features of the iXblue Photonics near-infrared modulators?

NGR: iXblue Photonics provides phase and intensity modulators in the near infrared operating from 780 nm to 1 150 nm with a modulation bandwidth of up to 25 GHz.
The key features of our modulators are:
- High optical input power handling with stable operating parameters such as Insertion Loss (IL), Polarization Extinction Ratio (PER), Static Extinction Ratio (SER) and DC-drift for amplitude modulators.
- Low IL.
- High PER.
- Very high SER.
- High electrical input power capability.

YD: We have very positive feedback from customers on the stability of the near infrared intensity modulators: is there any secret to this?

NGR: Yes, this is linked to optical power handling. It is well known that $LiNbO_3$ modulators become more susceptible to photorefractive effect at shorter wavelengths. It is for that reason that we have designed all our near infrared modulators with a focus on stability and low drift.
There are essentially two reasons why our modulators are the most stable on the market.
The first reason is because we use an X-cut configuration for the crystal: this helps provide good stability over temperature and minimize what is called the pyroelectric effect.
The second reason we excel in stability is because of the optical waveguide process that we use. It has been demonstrated that our state-of-the-art Proton Exchange process helps to decrease the photorefractive susceptibility. To compare to the widely used Titanium in-diffusion process, our proton exchange process is many times more resistant to the optical power density at such short wavelengths.

YD: I understand your proton exchange process generates a polarizing waveguide which has some advantages?

NGR: Indeed, a key feature of our modulators is that the waveguide is polarizing. This provides an excellent output polarization extinction ratio from a fibered phase or amplitude modulator.

YD: You have mentioned low optical insertion loss in your list of key features could you elaborate on this?

NGR: iXblue has a patented waveguide design that allows us to consistently achieve low insertion loss and maintain very high extinction ratios.

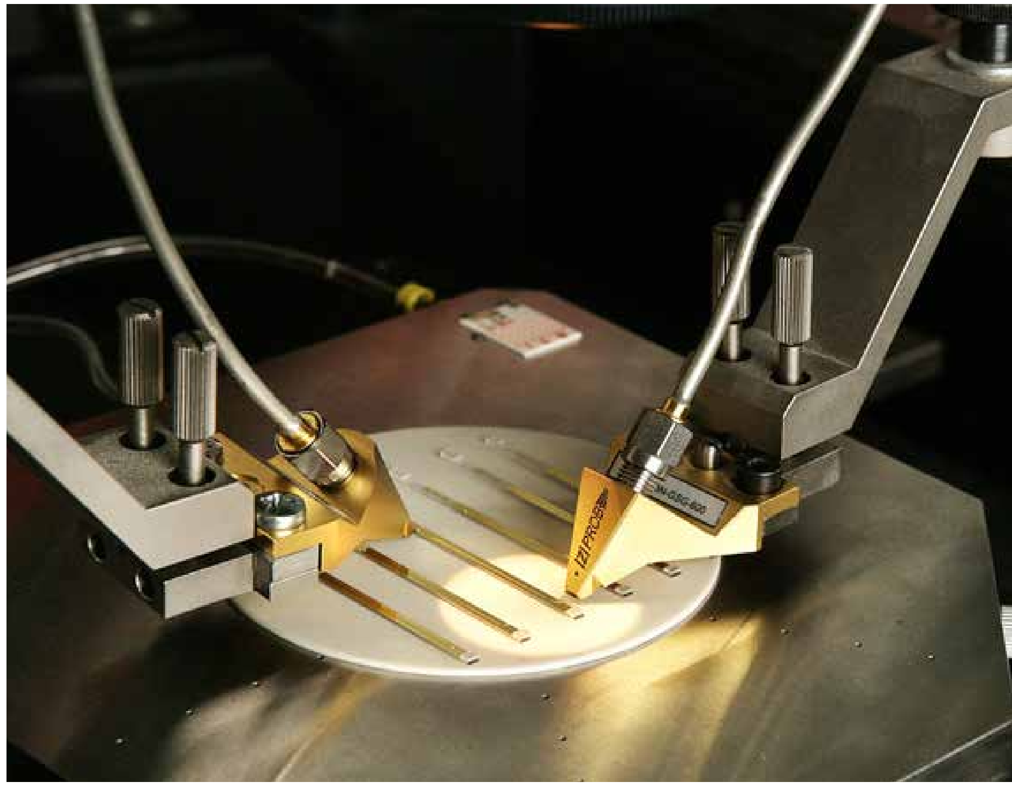
YD: It sounds like we can make an excellent intensity modulator with that. What are some applications for the near-infrared intensity modulators?

NGR: These modulators are typically used for sub-nanosecond optical pulse generation, pulse carving or pulse picking. We need to point out that our near infrared intensity modulators can provide an optical extinction ratio near 40 dB single stage.

Also, because they have a wide EO bandwidth, we can produce optical pulses with less than 20 ps rise and fall times. In fact, iXblue Photonics also provides turnkey solutions called ModBoxes that are used for high energy laser front ends.
We also see a renewed interest in the telecom industry for Reference Transmitter at 850 nm to test receivers. We have an excellent intensity modulator at 850 nm with a specific electrode design to generate 50 Gb/s-NRZ and 32 Gbauds-PAM4 modulation schemes. This product is also impedance matched at 50 Ohms for optimal performance with the drivers (RF amplifier).

YD: What about the near-infrared phase modulators, what are people using them for?

NGR: There are a lot of applications where the phase modulators are used. For instance, for frequency shifting, spectral broadening, coherent beams combining, Frequency laser locking by Pound-Drever-Hall technic, spectroscopy…
There is also a growing community using our modulators for atom trapping and cooling: 780 nm for Rubidium and 850 nm for Cesium.
We see some emerging spectroscopy applications in the 900 nm range and we have recently released the NIR-MPX900 to address this market and provide modulation solutions over 780 nm to 1 150 nm.
For some fiber laser applications, the interest for our phase modulators is generated by good optical power handling (up to 200 mW) and low RIN (<1 %).
Note that our phase modulators are also X-cut and feature a low insertion loss of < 3 dB with an optical output polarization extinction ratio greater than 25 dB.
Another key feature is that they can handle high electrical power, which is a key point for some applications such as sideband generation.



YD: There is always room for improvement so what can we expect in 2018?

NGR: We are working on improving the optical power handling of our modulators.
There are two issues we need to tackle: photorefractive effect and pigtail to chip interface.
A way to reduce photorefractive effect is to use a specific $LiNbO_3$ substrate.
A few years ago we started using these $LiNbO_3$ substrates for our modulators at 800 nm. This allowed us to increase the power handling with stable operation from 10 mW to 50 mW in the 800 nm wavelength window.
Our belief is that this specific $LiNbO_3$ substrate will provide even better stability for our phase and intensity modulators in the 1060 nm wavelength range. This new product will start shipping in Q1 2018.
Today, the first prototype characteristics show a very good IL and DC-drift stability up to 200 mW and we believe that stability can even be kept with higher optical powers.
However, for us to be able to provide higher optical power handling, we need to tackle the pigtail to chip interface and validate a reliable coupling method that will sustain as much as 500 mW or more.
Our goal is to have a solution early 2019.

YD: I know some NIR modulators have been deployed to space: can you comment on the availability of space qualified components?

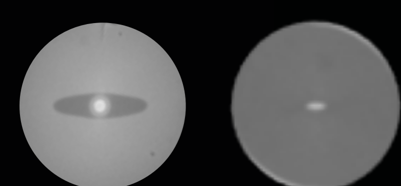
NGR: Yes, we indeed have several modulators that have been sent to space. In fact, iXblue is making fiber based gyroscopes and some of them have been flying in space for a while now, integrating our Y-junction phase modulator chips.
There are additional steps that need to be taken in terms of packaging to make sure the modulator will sustain the vibrations during take-off, temperature fluctuations, radiations and operation in vacuum.
We have experience working on several of these space projects over the years. I think we have a good understanding of what is needed in terms of performance and testing to provide a space qualified solution for our customers. ■

SCHEMATIC LAYOUT OF AN OPTICAL CURRENT SENSOR

A **fiber optic current sensor** (FOCS) is a sensor meant for measuring direct current.

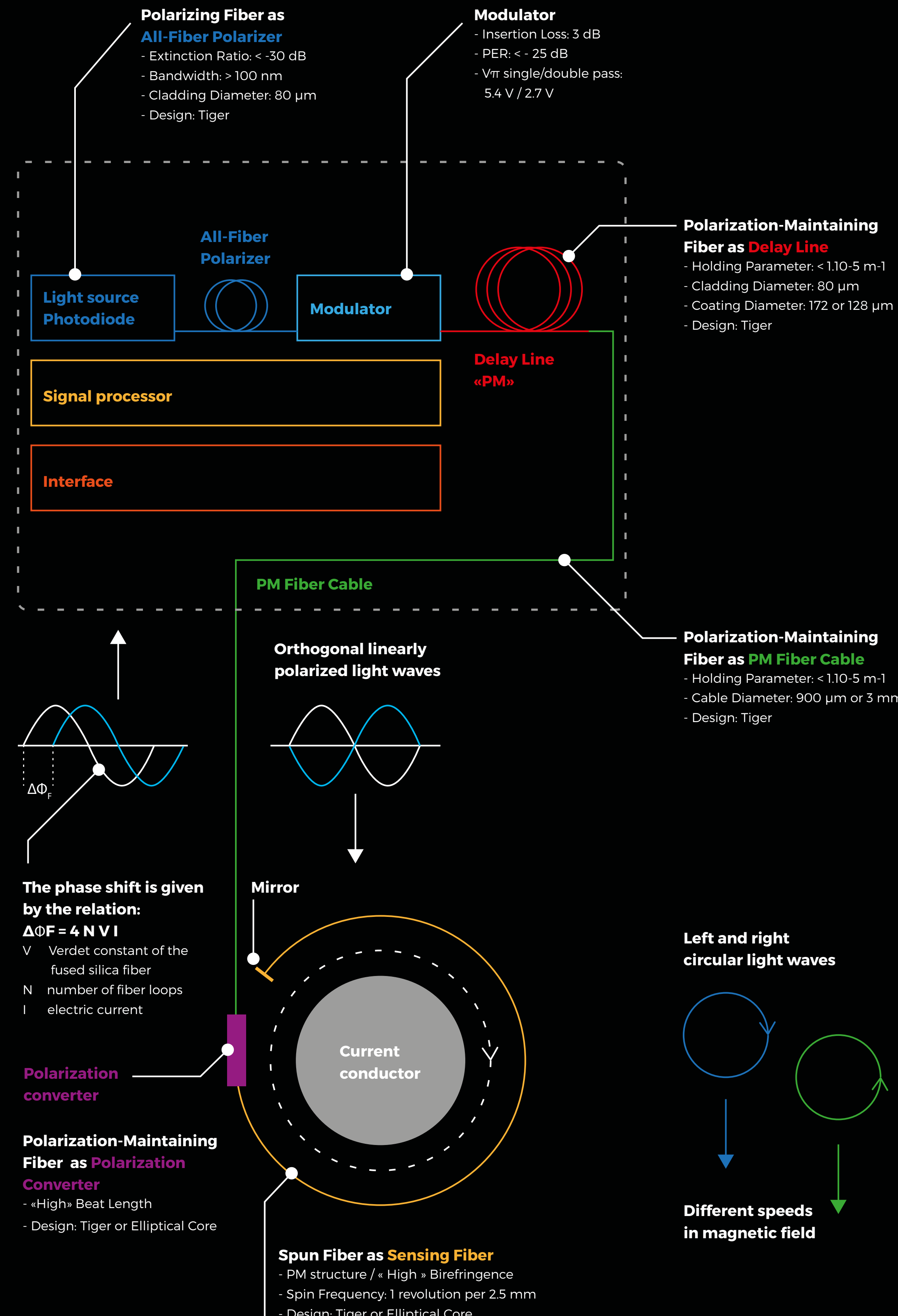
It is based on magneto-optic Faraday effect: two circular polarizations are launched through the coil of the sensing fiber wound around the current conductor; the phase shift between these two polarizations is directly proportional to the DC current to measure.

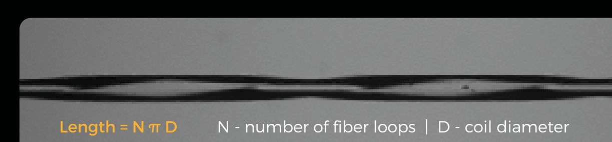
See how iXblue PM, Polarizing and Spun Fibers, as well as Modulators can help you build a robust and long-term reliable FOCS.



Tiger design E-Core design

The beat length temperature dependence of an elliptical core fiber is lower than those of Tiger, Panda or Bow-Tie designs





02

NEW PRODUCTS

MXIQER MODULATOR WITH MBC-IQ-DG-LAB

900 NM BAND AMPLITUDE AND PHASE MODULATORS

MODULATOR BIAS CONTROLLER: MBC-DG-LAB

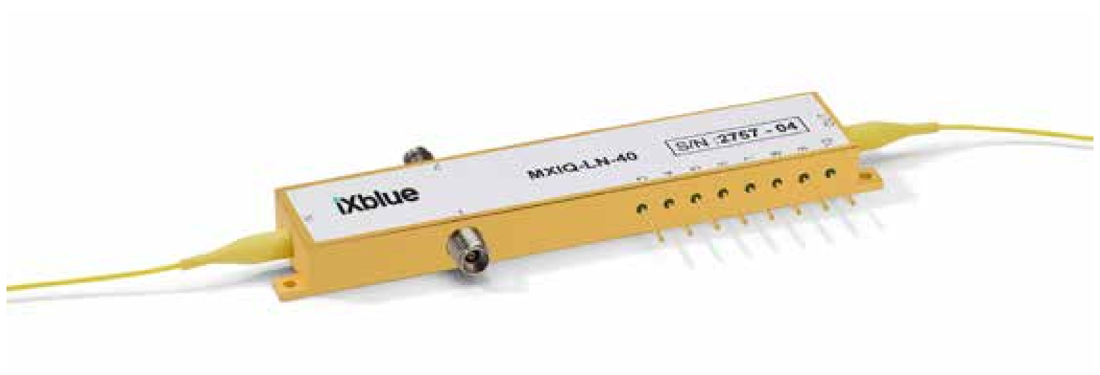
MODBOX-PAM-4

DOUBLE CLAD PM NEODYMIUM FIBER

THULIUM AND HOLMIUM CORE PUMPED FIBER

IXBLUE NEW OPTICAL FIBER STRIPPER TOOL «STIX»

MXIQER MODULATOR WITH MBC-IQ-DG-LAB

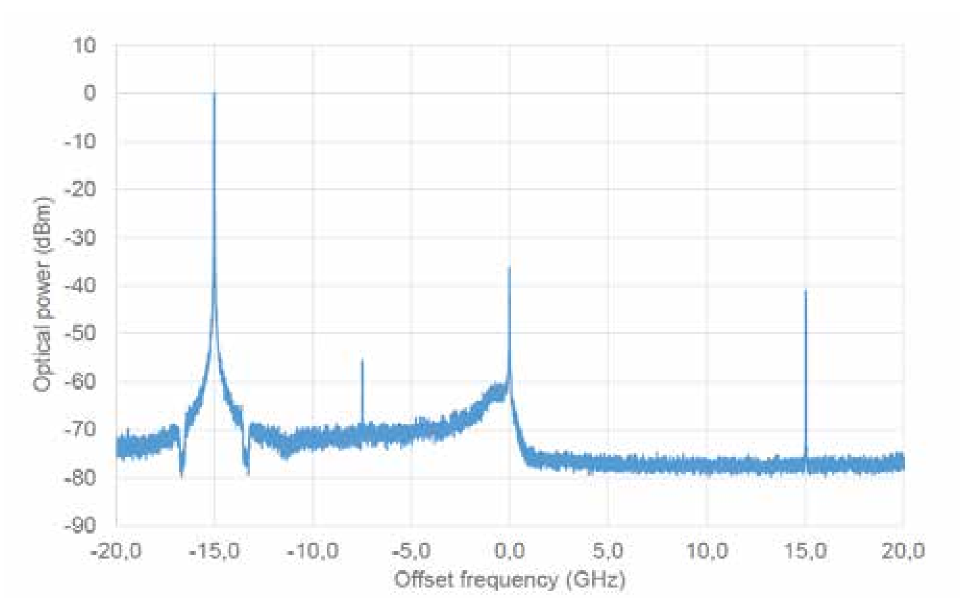


This new MXIQER is a dual-parallel modulator featuring a superior Extinction Ratio. The MXIQER modulator is a key device in all applications where a combination of high extinction and high bandwidth is required, such as complex modulation schemes QPSK, QAM, OFDM and Carrier Suppressed Single Side Band (CS-SSB).

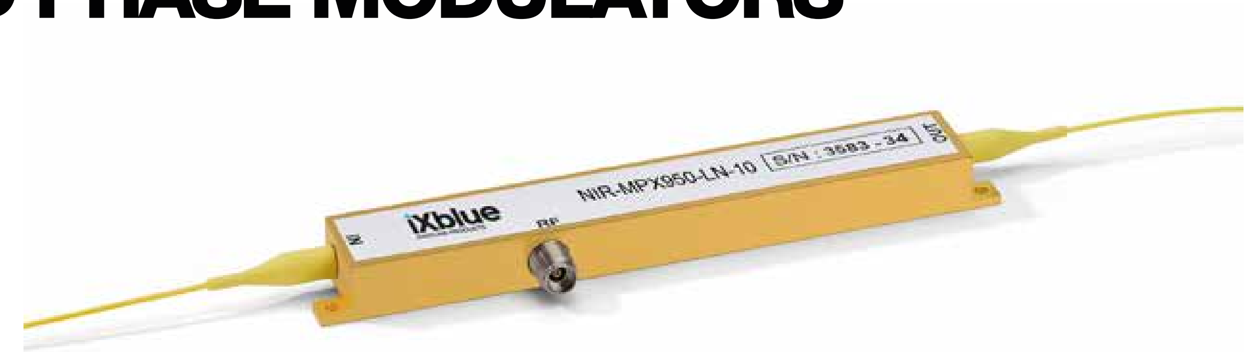
For CS-SSB application, the MXIQER modulator is delivered with the measurements of the Carrier and one of the Side band suppression and are warrantied > 32 dB.

iXblue's new MBC-IQ-DG-LAB is an electronic Bench-top especially designed to bias MXIQER modulator to ensure high quality optical properties over time.
The MBC-IQ-DG-LAB comes with a fully automatic mode to bias the sub-Mach-Zehnder at the NULL points and the QUADRATURE phase shift between the I and Q signals.

MXIQER with MBC-IQ-DG-LAB: Optical CS-SSB modulation with carrier and subcarrier suppressions



900 NM BAND AMPLITUDE AND PHASE MODULATORS



These Amplitude NIR-MX950 and Phase NIR-MPX950 modulators come with reduced insertion loss and feature unparalleled high-power handling capability.

The legacy NIR-MX (1060 nm band) and NIR-MX800 (800 nm band) are now complemented by new 950 nm band Amplitude and Phase Modulators covering the full optical spectrum from 850 nm to 960 nm. This addition to the iXblue Photonics near infrared electro-optic modulator portfolio certainly strengthens iXblue leadership on that market.

To help customers on the modulator choice, a modulator selection by wavelength guide is provided below.

Operating Wavelength	Applications	Modulators
976 nm 980 nm 1030 nm 1053 nm 1060 nm 1064 nm 1083 nm	· Fiber amplifier seeding and narrow optical pulse generation · Fiber laser locking (PDH) · Spectrum broadening and frequency shifting · laser combining · Quantum optics and Spectroscopy: 1083 nm: metastable helium	Phase NIR-MPX NIR-MPX-LN-0.1 NIR-MPX-LN-02 NIR-MPX-LN-05 NIR-MPX-LN-10 NIR-MPX-LN-20 Amplitude NIR-MX NIR-MX-LN-10 NIR-MX-LN-20
895 nm 914 nm 920 nm 940 nm	· Fiber laser locking (PDH) · Spectrum broadening and frequency shifting · Quantum optics and Spectroscopy: 895 nm: Cesium D1 line	Phase NIR-MPX950 NIR-MPX950-LN-0.1 NIR-MPX950-LN-05 NIR-MPX950-LN-10 Amplitude NIR-MX950 NIR-MX950-LN-20
770 nm 780 nm 785 nm 795 nm 808 nm 852 nm	· Fiber laser locking (PDH) · Spectrum broadening and frequency shifting · SR-4 Digital modulation · Quantum optics and Spectroscopy: 770 nm: Potassium 780 nm: Rubidium D2 line 785nm: Raman spectroscopy 795 nm: Rubidium D1 line 852 nm: Cesium D2 line	Phase NIR-MPX800 NIR-MPX800-LN-0.1 NIR-MPX800-LN-05 NIR-MPX800-LN-10 NIR-MPX800-LN-20 Amplitude NIR-MX800 NIR-MX800-LN-10 NIR-MX800-LN-20

MODULATOR BIAS CONTROLLER: MBC-DG-LAB

iXblue Photonics introduces the new MBC-DG-LAB automatic bias controller to lock the operating point of $LiNbO_3$ Mach-Zehnder modulators and to ensure a stable operation over time and environmental conditions. The new MBC-DG-LAB controller features improved sensitivity and stability.
The MBC-DG-LAB controller is dither signal based (a ditherless version MBC-AN is also available and dedicated to analog modulation), and overlays a low amplitude, as well as a low frequency tone (dither) on the modulation signal. The controller is continuously tunable, allowing to operate the modulator at any point of its transfer function. It can thus be used for Digital and Pulse applications, independently of the power of the laser source.

This new controller is also easier to use, thanks to various new features such as an AUTOSET operation for the QUAD/NULL/MAX modes, a Graphical User Interface (GUI), the storage and recovery of the user parameters and a USB communication.

MODBOX-PAM-4

iXblue Photonics offers Optical Reference Transmitters for -SR4 multimode and -ER4 -LR4 monomode LAN-WDM & C-WDM applications.
In addition the high quality NRZ and VNA Optical Transmitters ModBoxes, the new and highly linear with wide bandwidth ModBox-PAM4-28Gbaud is now available.

The ModBox-PAM4 generates excellent quality optical data streams PAM-4 up to 28 Gbaud and NRZ up to 28 Gb/s. The transmitter produces very clean eye diagrams with high SNR and fast rise and fall times. It also provides flexibility for adjusting the extinction ratio for vertical eye closure.

The Optical Reference Transmitter ModBox-PAM4 is the unique Transmitter available on market offering an optical modulated output power signal of at least 5 dBm at 850 nm, 1310 nm or 1550 nm.

DOUBLE CLAD PM NEODYMIUM FIBER

This new addition to iXblue double clad specialty fiber portfolio is based on an innovative refractive index profile, a five micrometer core combined with an eighty micrometer cladding to maximize the multimode absorption.

Standard Nd-doped fiber presents a much higher gain at the $^4F_{3/2} \rightarrow {}^4I_{9/2}$ transition - near 1060 nm - due to its true four-level nature. This fiber is designed with a W-type core refractive index profile that suppresses effectively the emission at 1060 nm through bend-induced losses. Pumped around 800 nm, the fiber exhibits high PER and optimized power conversion efficiency in the 900-940 nm window with no residual 1060 nm emission.

This fiber will be an excellent building block when designing a fiber laser emitting in the 900 to 940 nm. Applications cover non-linear spectroscopy, quantum optics, biochemistry and bio photonics.

Product code: IXF-2CF-Nd-PM-5-80-W

Associated passive fibers, as well as a fiber combiners adapted to this fiber are also available from stock.

	Parameter	Specification	Units
1	Core diameter	5 ± 0.5	µm
2	Clad diameter	80 ± 3	µm
3	Coating diameter	170 ± 15	µm
4	Core NA	0.16 ± 0.02	
5	Cladding NA	≥0.46	
6	Clad absorption @800 nm	>0.35	dB/m
7	Multimode background losses	<50	dB/km
8	Birefringence	$>2.10^{-4}$	
9	Core-clad offset	<1.0	µm
10	Proof test level	100	kpsi

THULIUM AND HOLMIUM CORE PUMPED FIBER

iXblue Photonics extends its polarization maintaining single-mode active doped fibers for core pumping fiber lasers and seeders by introducing 2 new fibers for 2 to 2.1 microns application. Double clad fibers have been well developed and commercialized in the past few years for high power amplifiers and CW fiber laser; those new fibers have been optimized to achieve lower RIN amplifier and seeder.

Key features:
- Core pumped amplifiers and seeder for 2 microns
- Low noise
- Optimized concentration
- PM and SM

Related Products:
Double clad Thulium and Holmium fibers
2 microns FBG

Type	Product Name	Core diameter (µm)	Cladding Diameter (µm)	Core NA	Coating Diameter (µm)	
Thulium doped fiber	IXF-TDF-4-125	4	125	0.27	245	
Thulium doped fiber, PM	IXF-TDF-PM-4-125	4	125	0.27	245	New
Holmium doped fiber	IXF-HDF-8-125	8	125	0.16	245	
Holmium doped fiber, PM	IXF-HDF-PM-8-125	8	125	0.16	245	New
Holmium doped fiber, PM	IXF-HDF-PM-20-250	20	250	0.08	340	New

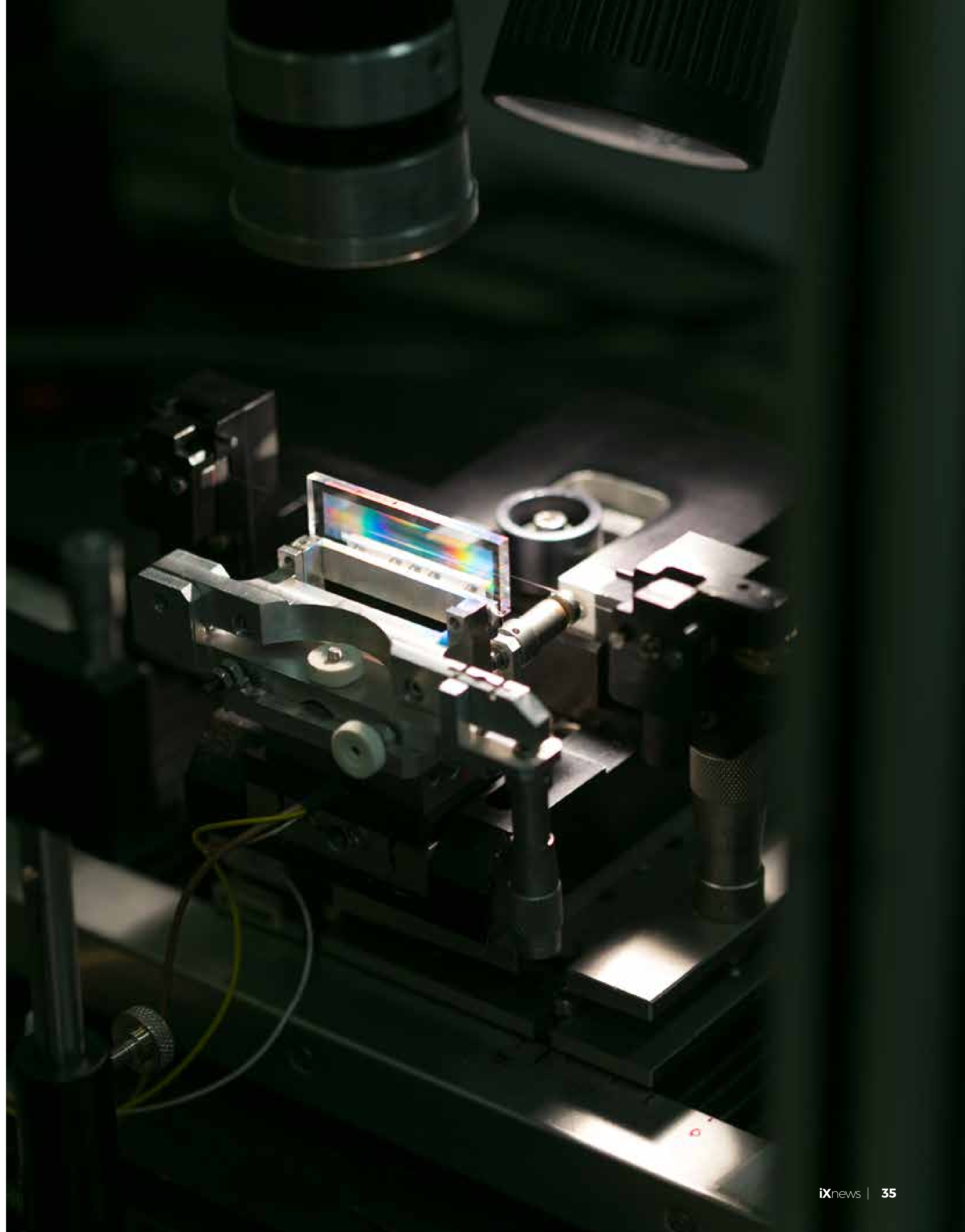
IXBLUE NEW OPTICAL FIBER STRIPPER TOOL « STIX »

You are working with Optical Fiber and need to remove fiber coating? You have a variety of tools available on your bench but cannot find the one most suited to this particular cladding and coating diameter? You need to try many times before getting an acceptable result with your standard stripping tool?

If this sounds familiar, we have the perfect solution for you. Because our engineers and technicians were not able to find a good stripping tool on the market, we decided to design one based on our 30 years hands-on experience working with optical fibers. This new stripping tool will easily adapt to any clad diameter, as well as any coating diameter, avoiding offset adjustment. Thanks to specific blades - that can be easily changed by the user when needed (after about 500 uses) - clean removal of coating without nicking the fiber's cladding is made possible.

Want a free sample?

Send an email to
stix.contest@ixblue.com
with your full contact details
(first and last name, shipping address, phone number, email address).
We will send a complimentary StiX to the first 50 emails received.
Contest Starts on January 30th, 2018.



LATEST SCIENTIFIC PUBLICATIONS

Over the past 20 years, iXblue has developed a unique expertise in the mastery of key photonics technologies from the manufacturing of radiation resistant fibers for nuclear environments and space applications to its latest developments on Neodym and Erbium-Ytterbium fibers. Engaged in largescale R&D projects, iXblue partners with major laboratories and organizations to always push the limits of science. Our publications reflect this desire to always go further to meet our customers ever increasing demanding requirements.

Electro-optic modulator and electro-optic distance-measuring device
Patent EP2839334
Co-written with Leica Geosystem
Original phase modulator designed to generate band-pass and symmetrical response in forward and backward electro-optic response.

Electro-optical phase modulator and modulation method
Patent CN105527733 (A)
FR3027414 (A1JP2016103002 (A)
US2016109734 (A1)
Specific and original study of phase modulators.

Evidence of photo-darkening in co-doped erbium-ytterbium double-clad fibers operated at high-output power
Presented at Photonics West 2018 – January/February 2018 – San Francisco, California, USA
Improvement of double clad EY fiber for high power and long term operation.

Gamma Radiation Tests of Radiation-Hardened Fiber Bragg Grating Based Sensors for Radiation Environments
IEEE Transactions on Nuclear Science Volume 64, Issue 8, Aug. 2017, pp 2307-2311
Co-written with Fraunhofer Institute, Laboratoire Hubert Curien, Areva and Smart Fibres

Large-mode-area fibers fabricated by the full vapor-phase SPCVD process
Presented at Photonics West 2018 – January/February 2018 – San Francisco, California, USA
Latest fibers developments based on SPCVD process.

$LiNbO_3$ Modulators qualified for space applications
28th European Symposium on Reliability of Electron Devices, Failure Physics and Analysis, ESREF

Novel multi-telescopes beam combiners for next generation instruments (FIRST/SUBARU)
Optical and Infrared Interferometry and Imaging V, Edinburgh, United Kingdom Proc. SPIE 9907
New generation of beam combiners that can ensure very sharp bend radius, high confinement and low propagation losses, together with lithium niobate phase modulators and channel waveguides that can achieve on-chip fast phase modulation.

Optimized radiation-hardened erbium doped fiber amplifiers for long space missions
Journal of Applied Physics 121, 163104 (2017)
Co-written with Laboratoire Hubert Curien, Politecnico di Bari, and the CNES
Focus on the third generation of Erbium Radiation fiber, Radiation induced gain Variation is below 0.005 dB/krad

Radiation hardened temperature measurement chain based on femtosecond laser written FBGs in a specific optical fiber
Presented at WSOF 2017 - 5th Workshop on Specialty Optical Fiber and Their Applications – October 2017, Limassol Cyprus
Co-written with Fraunhofer Institute, Laboratoire Hubert Curien, Areva and Smart Fibres
iXblue developed a custom single mode fiber able to work under high irradiation and high temperature.

Radiation influence on Er and Er/Yb doped fiber amplifiers performances: High power and WDM architectures
Presented at Photonics West 2018 – January/February 2018 – San Francisco, California, USA
Co-written with Laboratoire Hubert Curien
Latest developments in doped optical fibers for space amplifiers.

Recent Progress on the Reliability and Hermeticity of Space Grade $LiNbO_3$ Modulators
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Reliability Assurance Guideline for Lithium Niobate-based Electro-optical Modulators
Presented at ISROS Conference - International Society on Reliability of Optoelectronics for Systems - Otwock, Poland

Robustness of astrix fiber optic gyros in space radiative environment
Presented at GNC 2017 – 10th International ESA Conference on Guidance, Navigation & Control systems – June 2017, Salzburg, Austria
Co-written with Airbus
Development of radiation resistant passive and doped fibers started 10 years ago at iXblue. With tens of satellites flying using iXblue Optical Fibers, we now have access to data from real space environment – not only lab irradiation testing.

Transverse mode selection in a Nd-doped fiber amplifier at 910 nm
Optic Express 25, 18314-18319 (2017)
Co-written with ENSICAEN
A major step toward « true » blue laser.

Tunable CS-SSB instrumentation for Brillouin applications
Presented during a workshop on OptoMechanics and Brillouin scattering (WOMBAT 2017) – July 2017 – Besançon, France
A feasible solution to generate a carrier suppressed single sideband (CS-SSB) optical source.

Watt-level single-frequency tunable neodymium MOPA fiber laser operating at 915-937 nm
Presented at Photonics West 2018 – January/February 2018 – San Francisco, California, USA
Co-written with LP2N

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