"The Glamorous" European project (glass-based modulators, routers and switches)

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Abstract

We will describe the European project Glamorous, which involves several research groups working in the field of poling of glass. Objectives and recent results on materials, devices and applications will be reviewed.

Summary

The GLAMOROUS project aims at taking the field of poling of glass to the demonstration of *active* glass-based components that are industrially viable. Activities range from materials to commercial exploitation of the poled devices. In particular the consortium plans:

- to use the deeper understanding gained on the mechanisms behind glass poling to model the effect, to optimise poling conditions (in terms of time, temperature and voltage), to increase the stability of poled samples (to >10 years at room temperature) and to design doped glasses where the effect is enhanced. By the end of the project, a nonlinear coefficient sufficiently high should be achieved in a reproducible way to lead to commercially viable devices;

- to design and fabricate fibres and planar waveguides suitable for poling, including special fibre structures (e.g. D-shaped and twin-hole fibres) with internal or external electrodes and

special dopants. A proposed target is to achieve uniformly and periodically poled fibres ≥1 m long. A second objective is the optimisation of poling techniques for fibres and planar waveguides in terms of temperature, time, voltage and geometry;

- to design, construct and package high performance devices based on glass technology capable of performing the critical tasks required to implement the functionality of the optical layer in optical networks. More specifically: a) Electroptical 2x2 switch (mainly for protection) with time response < 100 μs and Driving voltage x Poled length < 10 Vm. Complementary specifications are Insertion loss (IL) < 1.5 dB, Polarisation dependent loss (PDL) < 0.5 dB, Polarisation mode dispersion (PMD) < 0.5 ps, Crosstalk < -30 dB, Return loss >40 dB, b) Wavelength converter with the following specifications: Conversion efficiency > -10 dB, Number of simultaneously switched channels ≥ 8 at <2 W pump power. Complementary specifications are IL < 2 dB (if in fibre), PDL < 1 dB, PMD < 1 ps, Return loss > 30 dB;

- to assess the technical work over the entire project period as well as the potentials for commercial exploitation, i.e. device cost against performance and functionality. The technical assessment will embrace all the aspects including the characterisation and performance measurements for starting materials, poling techniques, fabrication, processing, fabricated devices before and after packaging, performance in systems testbeds, and costs;

- to disseminate the results of the project to a public much beyond the group of participants. To publicise the work to both scientific and industrial communities, within and outside the EU and finally, to assess the market for the fabricated devices and the added value to the EU community and exploiting commercially the results, always within the established IPR agreements.

During the first year promising results have been achieved. We summarise them following the work-package (WP) list. We point out that most of the work concerns the WPs on materials (WP1) and processing (WP2). The effort in the other WPs was lower and will increase during over the next years.

WP1: Basic studies and optimisation of materials
Besides conventional silica glasses currently used in fibre and waveguide fabrication, GLAMOROUS decided to focus on the study of glasses with transition temperature >400 °C and no sodium, for increased stability. The following glass families were fabricated: multicomponent boron-doped silica; telluride; chalcogenide; non-silica heavy-metal oxide; film using PECVD and IDECR for waveguide poling work. After promising results obtained by resonance enhancement of $\chi^{(3)}$, an additional activity was started to indiffuse nanoparticles of metal into silica-based glasses. The Consortium has had a continuos supply of new glasses for poling studies.

The samples fabricated were probed by various techniques for their optical quality and $\chi^{(2)}$ induced by poling. (1) Conventional optical characterisation; (2) Determination of amplitude and profile of $\chi^{(2)}$ induced in bulk samples by improved Maker Fringe method; (3) Second harmonic scanning microscopy (4) Defect density and stability by electron spin resonance; (5) Secondary electron emission; (6) Evaluation of the following poling techniques: (a) alternate field, where a 13x increase in SH was measured in high-purity glass; (b) UV; (c) UV plus corona; (d) UV pre-treatment; (e) γ-ray pre-treatment; and (f) IR fs-pulse pre-treatment. Both (d) and (f) are techniques with good spatial resolution and enhanced nonlinearity in the pre-exposed region, which can be exploited in wavelength converters.

WP2: Fabrication and processing

Fibres for electrooptical switching and wavelength conversion were designed. Issues addressed include the electric field distribution in internal electrode fibres, fibre attenuation for various core-hole distances and polarisation dependent loss. Both the attenuation and PDL were compared with experiments. A new Mach-Zehnder interferometer fibre was designed and a preliminary test fibre drawn. Various fibres with internal holes were manufactured.
A technique was demonstrated to insert metallic electrodes for long device fabrication (>1 m) using molten alloys at high temperature and pressure. Another processing technique of depositing silver films inside the holes was developed.

The activities on planar waveguides for wavelength conversion included the fabrication by PECVD of silica glass structures with Ge:SiON core on Si substrates. Channel waveguides were UV-written or etched/regrown. Metal inclusion was achieved by sputtering and diffusion prior to poling, and silver indiffusion during positive poling. Resonance enhancement of $\chi^{(3)}$ with indiffusion of Ag was exploited for high nonlinearity at 800 nm. The optical properties of the metal-doped glass were studied, and the complications of loss and dispersion were addressed.

WP3: Devices

A 1-meter long Kerr type switch was tested, using the Mach Zehnder type fibre developed. The solid internal electrodes were inserted in molten form. A switching voltage (quadratic dependence) of about 1 kV was measured.

A new technique for periodic electrode fabrication was demonstrated in internal electrode fibres. A laser beam impinging from the side of the fibre periodically ablated the silver film deposited inside the holes. Second-harmonic generation was demonstrated in periodically poled waveguides.

WP4: Measurement and evaluation of results

The various glass families fabricated in WP1 were assessed. The fibres with internal electrodes fabricated in WP2 were evaluated in terms of PDL by three groups in the Consortium, and limits to device lengths were inferred.

WP5: Dissemination and exploitation of results

The technical and commercial targets of the project were defined. The technical targets are an all-fibre 2x2 switch with time response <100μs and 50 V switching voltage and a wavelength converter for 8 WDM channels with an efficiency >–10dB at pump power levels <2W.

For a more detailed description of the results obtained in Glamorous please refer to the numerous submissions to BGPP from the groups collaborating in the project.