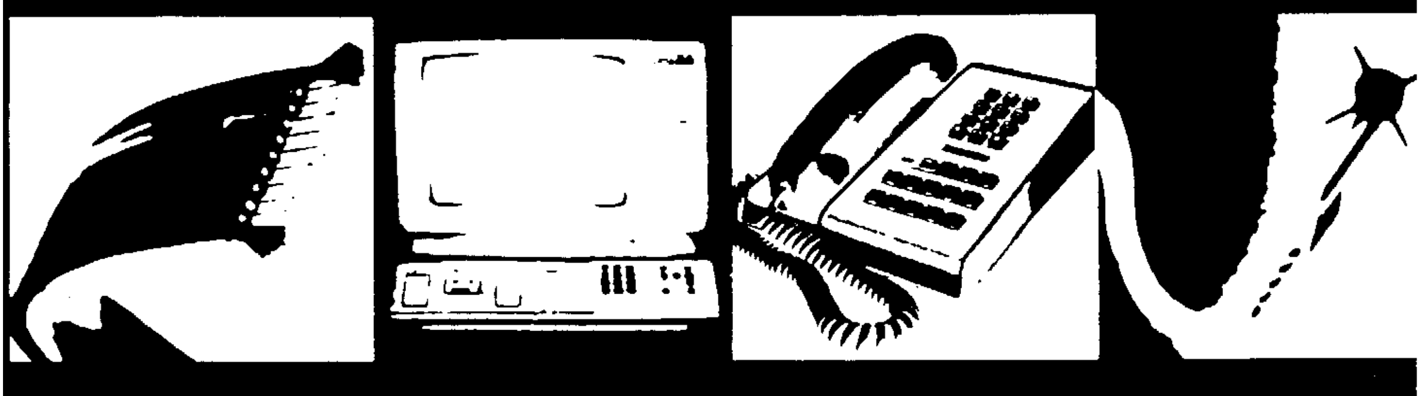
The Sixth International Fiber Optics
and Communications Exposition
Sept. 15 - 17, 1982
Los Angeles Marriott Hotel

FOC 82

Proceedings



Edited by Fitzgerald, O'Bryant and Polishuk
Published by Information Gatekeepers, Inc.

OPTICAL FIBRE TECHNOLOGY BY TRIPLE AND QUADRUPLE CRUCIBLE METHODS

Jan Dorosz
Glass Works "Bialystok"
Bialystok, Poland

Ryszard S. Romaniuk
Technical University of Warsaw
Warsaw, Poland

Abstract

TC/QC optical fibres have probably been pulled in leading laboratories carrying out the research in the domain of multicomponent glass fibres, but authors have not found direct references concerning the detailes of this subject. There are described rather multilayer fibres of varius constructions made by CVD or phase separation technology, for instance: optical fibres with divided or multiple cores, with multiple claddings, of quasi-step, W-type or ring-type refractive index profiles. Thus, the work is the first to describe theoretical, technological and aplication problems connected with multilayer optical fibres of sophisticated refractive index profiles made by multicrucible method.

Justification of the work

Triple and quadruple crucible fibres were the subject of investigations because of several important reasons:

1.Double crucible method /DC/ has confined possibility of shaping of optical fibre refractive index profiles. Only triangle, parabolic, quasi-step and step-index profiles can be shaped by means of changing of a diffusion length. Much broader field give triple and quadruple crucible methods. They permit, in the course of comparatively simple and continuous process, to obtain W-profiles, ring-profiles, multistep-profile fibres in their quasi-step and gradient versions.

2.Optimal multi- and monomode optical fibres /as far as geometrical relative dimensions, glass compositions and refractive index profiles are concerned/ have been looked for several purposes:

a.short integrated and nonintegrated optical fibre bundles of extremely high quality,

b.optical fibre transducers and elements of fibre microoptics,

c.optical fibres polarization maintaining,

d.optical fibres of extremal izotropy.

3.Multicrucible technology gives broad possibilities of basic technological investigations like: various glasses mutual bonding, diffusion of constituents and dopants, pulling of glass in complex structures, covering the fibre waveguide with various substances - for instance magnetostrictive glasses, termical and mechanical investigations of complex fibreous structures stating mutual functional dependences of technological parameters influencing the pulling process like: h_i-levels of liquid glasses or local pressures in crucibles - p_i, d_i-distances between crucibles outflows, glass parameters, v-speed of pulling, l_{di}- diffusion lengths, ϕ_i- diameters of outflows from crucibles, t_i-partial temperatures of various partly isolated furnace regions. In particular, the multicrucible technology gives the possibility of zonal glass melting /multichamber melting/. The last method developed originally by the authors can lead to the bonding of glasses of different termical characteristics.

Basic aims of the work

Presented work has three general aims. The first one is to show the possibility of performing of TC/QC stable fibres from the point of view of basic technological investigations like pulling of fibres from various glasses of different compositions and termical characteristics. The second one is to investigate the possibility of shaping mostly sophisticated refractive index profiles. It seems, that in this field TC/QC methods have certain advantages over CVD process, especially in the range of high NA value fibres. The third one is to investigate the possibility of applications of multilayer fibres of extremely complex refractive index profile.

Experiments

Optical fibres were pulled from three and four crucibles placed in a graphite resistance furnace using compound glasses like: SK, BaLF, SLS, SBS, etc, for various debated technological parameters of the process. Main characteristics of optical fibres made by TC/QC methods were displayed and discussed. Main attention was focused on the process of shaping of refractive-index proffile of optical fibres. Various classes of refractive index profiles were debated and relevant fibres pulled. The most interesting subject under investigation were dopants diffusion processes. Diffusion processes were traced by means of an electron microprobe.

Transmission experiments on a certain length of TC/QC fibres were successfully carried out. Some of the TC/QC fibres were applied in various sensors systems like: optical fibre two-color pirometry, optical fibre termometry and tonometry. The results will be shown during the conference.

Investigation of diffusion processes in multilayer optical fibres

The main problem appearing now in the technology of multilayer optical fibres is their stability in terms of basic parameters as functions of a fibre length. Among these, refractive index profiles play the most important role. The crucibles were filled with a melt without refilling the mass decrement during the process. This was caused by very sophisticated geometry of a pile of three or four crucibles. In the newer version of technological equipment, however, the lack of, at least four-fold, refilling machine will be complemeneted. This will give the possibility to investigate the equilibrium of mass outflows from as many as four crucible nozzles.

The levels of melts changed during the process influencing not only the geometrical dimensions of a fibre but also refractive index profile through the direct insult on the diffusion processes. Keeping other technological parameters steady and tracing the refractive index profile as a function of temperature and melt levels, there were carried out broad investigations of diffusion phenomena during the various stages of pulling. In other pulling experiments there were changed slightly glass compositions so as to enable tracing the influence of the levels of glass dopants on the diffusion processes.

Suitable choice of: glass compositions for different layers of fibre, distances between crucible nozzles, dimensions of nozzles, speed of pulling, temperatures of the process allow to obtain planned refractive index profile of a multilayer multicrucible optical fibre. The work contains a debate on the technological conditions leading to certain kinds of refractive index profiles, as well as, a debate on the changes of the profile during the process of pulling.

Refractive index profiles were measerd by means of an interferometric method using interferometric-polarizing "shearing" microscope. Compensating the refractive index of an out-er layer by means of an immersion fluid and utilizing known methods, the profiles were determined. In particular, for multilayer fibres the zonal approximation method is very well suited [1]. Certain idealization like that the mentioned measurement methods require radial symmetry of a fibre and does not take into consideration, in the first stage of approximation, the refraction of a measuring beam, deteriorate reached accuracy of measurements. The results of measurements, despite certain simplifications and assumptions imposed by the used method, are a good confirmation of technological data and give precious information indispensable for stating the quality of a fibre and suggesting some applications.

There were drawn a few conclusions from the performed numerable measurements of many optical fibre samples taken out from different phases of the fibre pulling process:

1.ion exchange processes between successive fibre layers are amplificated or suppressed by changing of the starting thickness of layers caused by non - uniform lowering of the melt in the crucibles,

2.one of the main problems of multicrucible technology /connected with complex pulling geometry/ is the stability of optical fibre parameters along its long axis from the point of view of the stability of ion diffusion, termical and pulling processes,

3.at the moment it seems that multicrucible fibres will create the main source for construction of fibre optic sensors.

Reference:M.Bożyk, Interferometric measurement of optical glass fibre refractive index profiles using zonal approx. method, Optica Applicata /in press/

Fig.1. Cross section of triple crucible optical fibre, technological data in table 1

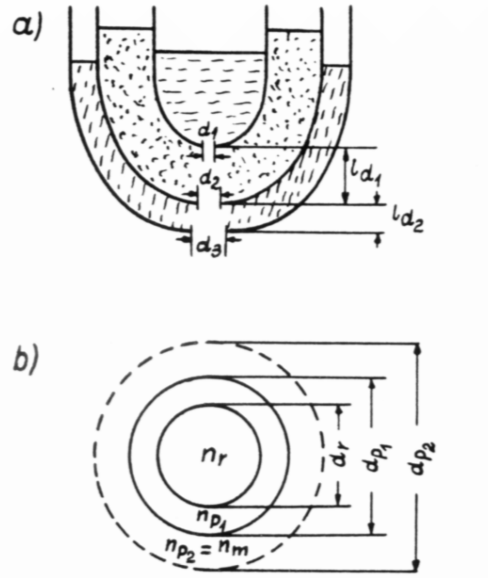


Fig.2. Triple crucible optical fibre geometry.

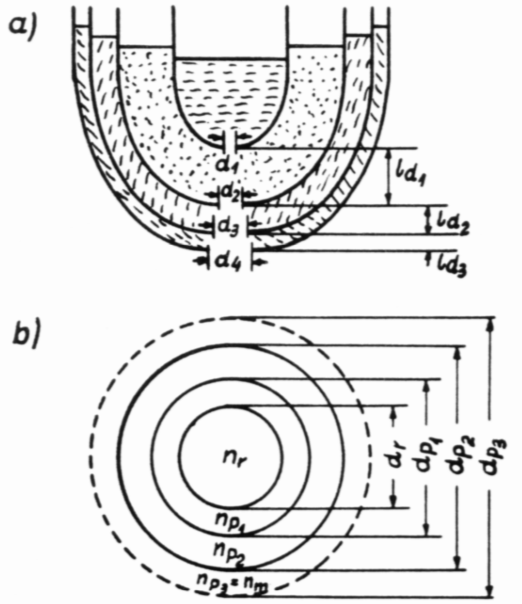


Fig.3. Quadruple crucible optical fibre geometry.

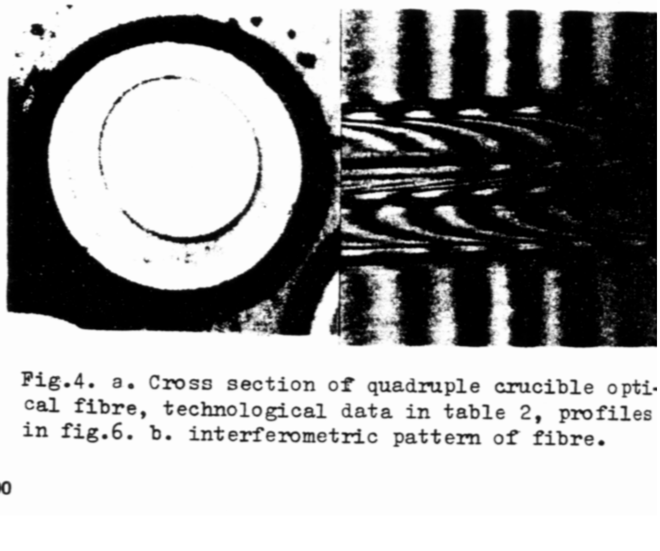


Fig.4. a. Cross section of quadruple crucible optical fibre, technological data in table 2, profiles in fig.6. b. interferometric pattern of fibre.

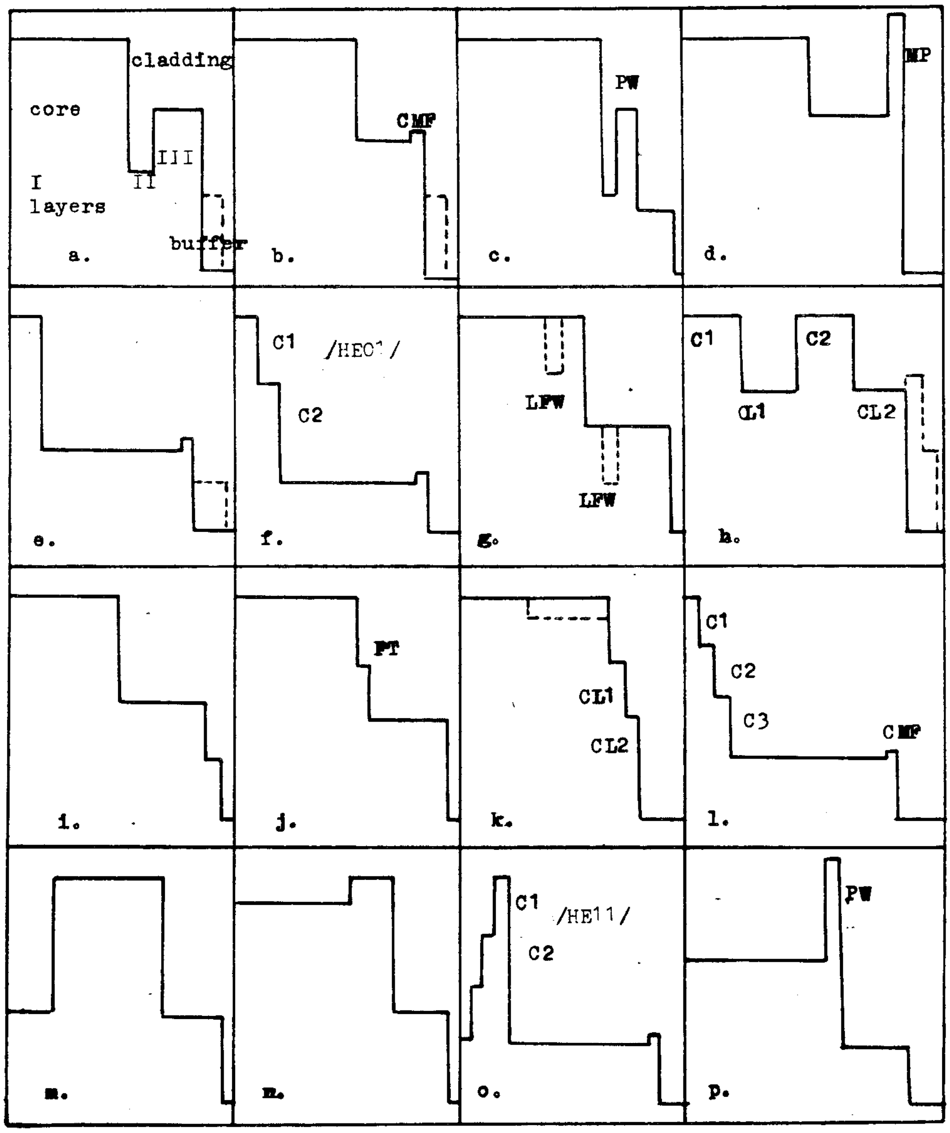


Fig. 5 Kinds of refractive index profiles of fibres pulled from three and four crucibles: a-h.-W-profiles, a. with tunneling effect, b.-without tunneling, c.-large cored with optical buffer, d.-with cladding modes drain /pump/, e.-single-mode, f.-multi-fold single-mode, g.-with local field weakener, h.-WW-type or ring two-core; i-l.-staircase profiles, i.-classical, j.-with local field transformator, k.-large cored with profiled core, l.-multi-fold single-mode; m-p.-ring-type profiles, m.-classical, n.-with profiled core, o.-multi-fold single-mode, p.-with potential barrier. Signs: CMF-cladding mode filter, PW-potential well, MP-modal pump, LFW-local field weakener, FT-field transformator,

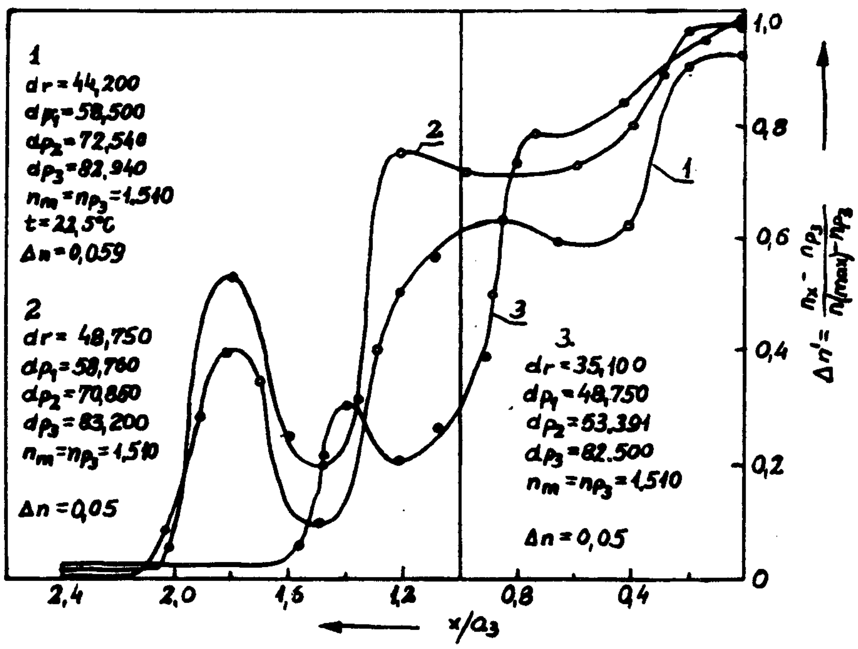


Fig.6. Refractive index profiles of quadruple crucible optical fibre.
1. beginning of the technological Process,
2. middle of the process,
3. end of the process.
a_3-radius of the core of fibre 3 .

Table 1. Triple crucible fibre - oxides composition

layer	kind of glass	Na_2O	K_2O	BaO	n = 550nm
			% in weight		
core I	SK12	-	-	37	1,5812
core part II	BaLF 5	2	14	11	1,5470
cladding	S 1	17	-	-	1,5130

Table 2. Quadruple crucible fibre - oxides composition

layer	kind of glass	Na_2O	K_2O	BaO	n = 550nm
			% in weight		
CORE I	BaK 4	4,6	5	20	1,5612
cladding I	BaK 2	3,5	10	19,2	1,5392
CORE II	BaK 4	4,6	5	20	1,5612
cladding II	S 1	17	-	-	1,5130

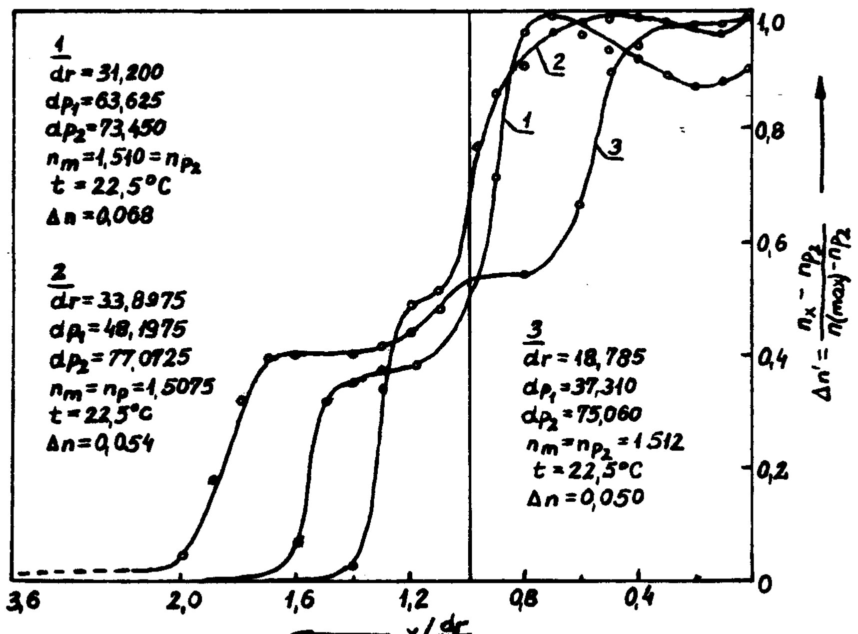


Fig.7. Refractive index profiles of triple crucible optical fibre.
1. beginning of the technological process,
2. middle of the process,
3. end of the process.
n_x-refractive index of given point x, the crucibles were not refilled during the process.