Grating writing through the fibre coating at 244nm and 248nm

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Abstract

High quality fibre Bragg gratings have been written through the fibre coating using both 244nm frequency-doubled Ar^{+}-ion and 248nm KrF excimer lasers for the first time. A standard off-the-shelf coating was used, and 92% reflectivity gratings were obtained with an index change of 2.4×10^{-4}.

Indexing terms: fibre gratings, coatings

Introduction

Fibre Bragg gratings are widely used in the fields of optical fibre communication and fibre sensor systems. In the normal process of fibre grating fabrication, all coatings must be stripped off and the fibre cleaned thoroughly before the grating can be written and, in order to preserve the mechanical strength of the fibre, it must be re-coated soon after the grating is manufactured. This procedure is both time consuming and has the potential of reducing the fibre strength due to exposure of the bare fibre to air. To solve the problem, a number of solutions have been proposed. These include using a specially developed UV-transparent polymer coating [1], writing the grating using near UV light around 330nm instead of at more conventional wavelengths [2], writing on-line as the fibre is being pulled [3] and using a specially developed coating which can be removed thermally prior to grating inscription then immediately re-coating in an automated production system [4]. The polymer used in [1], although it has a lower absorption than the normal UV-curable polymer coating, still has strong absorption below 260nm. This increases the grating writing time and reduces the mechanical strength of the fibre when higher UV exposure is used [5]. In [2], a specially developed phase mask is needed in order to operate at the non-standard wavelength, together with an increased exposure time due to the reduced UV absorption. In addition, care is also required to control the average laser power in order to reduce damage to the coating. On-line production of fibre gratings [3] is limited to the manufacture of gratings which can be made with a single laser pulse. The method proposed in [4], although attractive, requires both a special coating and an automatic production system. Furthermore, a thermally strippable coating also suffers from low heat resistance in many applications. In this letter, we demonstrate for the first time writing of high quality fibre gratings through a normal off-the-shelf fibre coating using the generally preferred wavelengths of 244 and 248nm. We show that the scheme is both simple and cost effective.

Experiment and results

The coating we used is General Electric RTV615 silicone rubber. This coating is thermally curable and thus does not require a UV absorbing photoinitiator. With a normal specified useful temperature range of –60°C to 204°C, the coating has a better thermal tolerance than standard UV curable polymer coating. This is an important advantage in many applications. To determine the absorption of the material in the UV region, a 150μm thick film of cured silicone rubber (thicker than a standard fibre coating) was formed between two silica plates. The absorption characteristics of the coating as measured using a spectrophotometer is shown in Figure 1. A silica plate was used as the reference to improve the measurement accuracy. The result clearly indicates a transmission of almost 92% for this coating thickness at a wavelength of 248nm. This low UV absorption suggests the possibility of Bragg grating writing through the silicone rubber coating using either a frequency-doubled Ar^+-ion laser at 244nm or a KrF excimer laser at 248nm. To verify this, we coated a photosensitive boron co-doped silica/germania photosensitive fibre (NA=0.12, $\lambda_{cut-off}$ =1050nm, diameter=125μm) with the silicone rubber coating. The average coating thickness was 60μm, similar to a normal fibre coating. Grating inscription was initially carried out using a 248nm excimer laser and a 1540nm phase mask optimised for 248nm operation. A 1cm long grating was produced by scanning a 3mm wide beam over a section of the coated fibre, each individual part of the fibre receiving an exposure of 3 minutes at 20Hz. The individual pulse fluence was set at $64mJ/cm^2$. The spectrum was monitored using an optical spectrum analyser and 1.55μm LED. A grating with a reflectivity of 92% was obtained (see figure 2), limited by the resolution of the optical spectrum analyser (approximately 0.1nm), corresponding to an index change of 2.4×10^{-4}. For comparison, we also stripped off the coating and exposed the fibre under identical conditions, and this grating is also shown in figure 2. The almost identical result suggests that the effect of writing through the coating is almost negligible.

In order to test for possible coating-induced thermal effects on grating uniformity, a 25mm long Blackmann apodised grating was written through the coating at 244nm using a frequency-doubled Ar^+-ion laser in a D_2-loaded sample of the same fibre, and the reflection characteristic of this result is shown in figure 3. The intensity in this case was $2.2kW/cm^2$ with a total fluence of $1kJ/cm^2$. It can be seen that most of the reflected light outside of the central peak is >30dB down on the peak reflectivity, indicating excellent grating uniformity and a grating quality well suited for wavelength-multiplexed sensor purposes. The index change obtained was 1.0×10^{-4}.

To verify the heat resistance of the coating we placed a fibre with the silicone rubber coating together with a fibre coated with UV curable polymer on a hot plate with a temperature of 300°C for 3 minutes. A visible darkening of the polymer was observed. However, the effect on the silicone rubber coated fibre was negligible.

Conclusions

In this letter we have demonstrated for the first time the ability to write high quality fibre gratings through standard fibre coating at the preferred wavelengths of 244 and 248nm. We have shown that the scheme is not only simple but also has several advantages over other previously demonstrated techniques. The ability to write through the fibre coating at these wavelengths is most useful since it will significantly simplify the grating writing process, particularly for long arrays of gratings as required for fibre sensors. The better heat resistance not only implies that it can be used in many different applications but also allows the grating to be annealed if there is such a requirement, *e.g.* after hydrogen loading.

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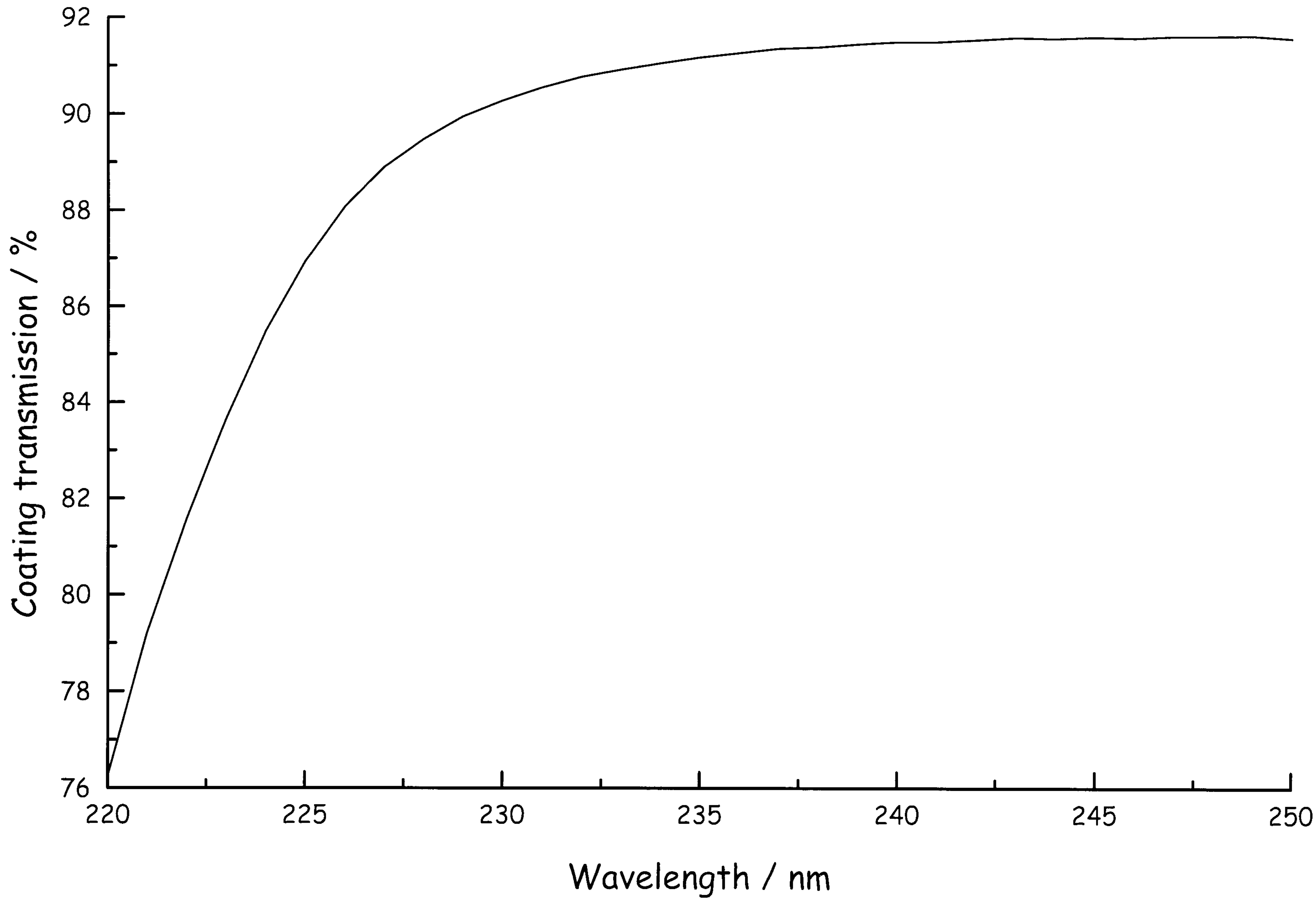
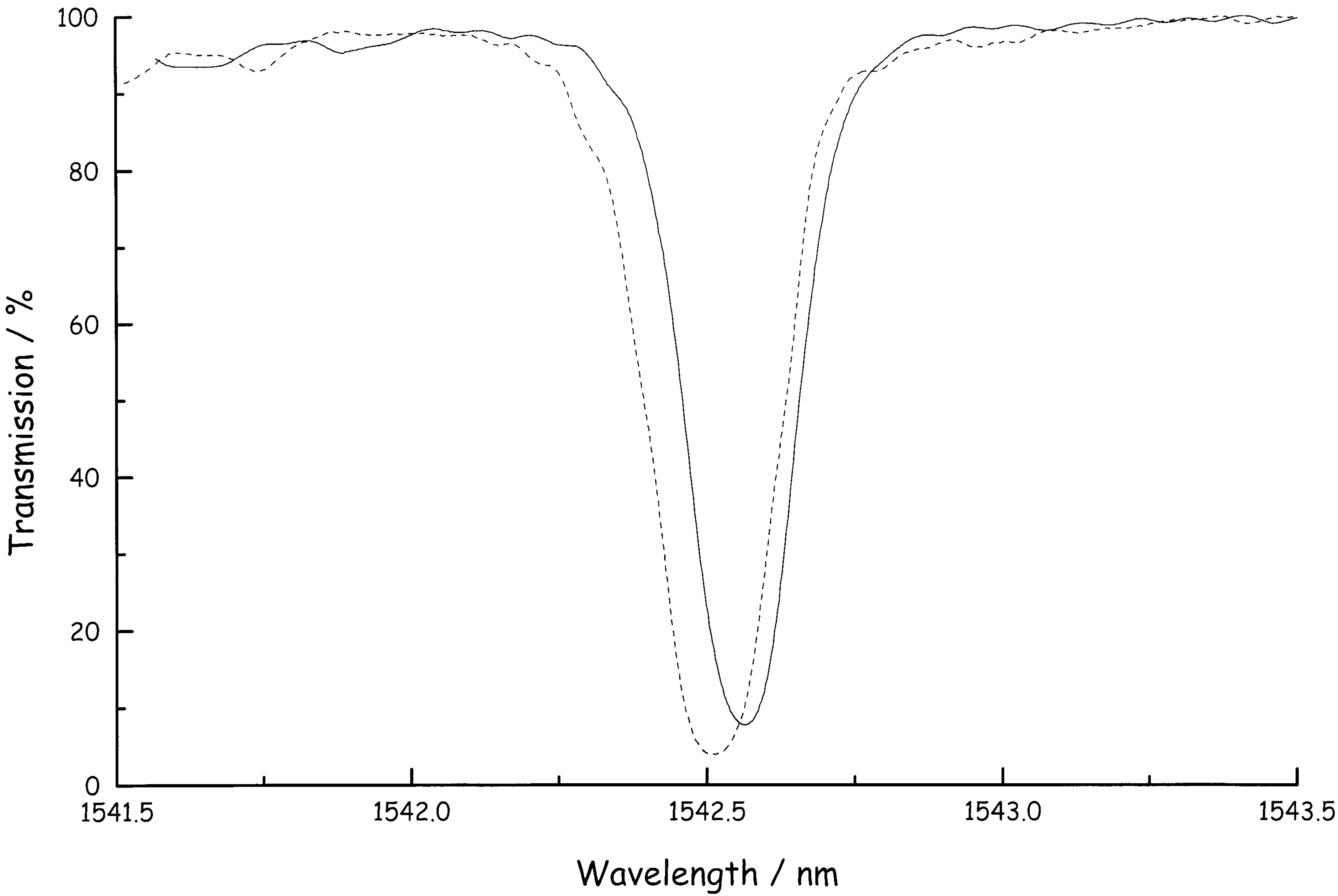
Figure captions

Fig. 1 Transmission characteristics of 150μm thick film of silicone rubber RTV 615 in the UV region.

Fig. 2 Transmission spectra of 10mm long Bragg gratings written in coated (solid line) and un-coated (dotted line) fibre.

Fig. 3 Reflection spectrum of a 25mm long Blackmann apodised Bragg grating written in coated fibre.


Coating transmission / %
92
90
88
86
84
82
80
78
76
220
225
230
235
240
245
250
Wavelength / nm


Transmission / %
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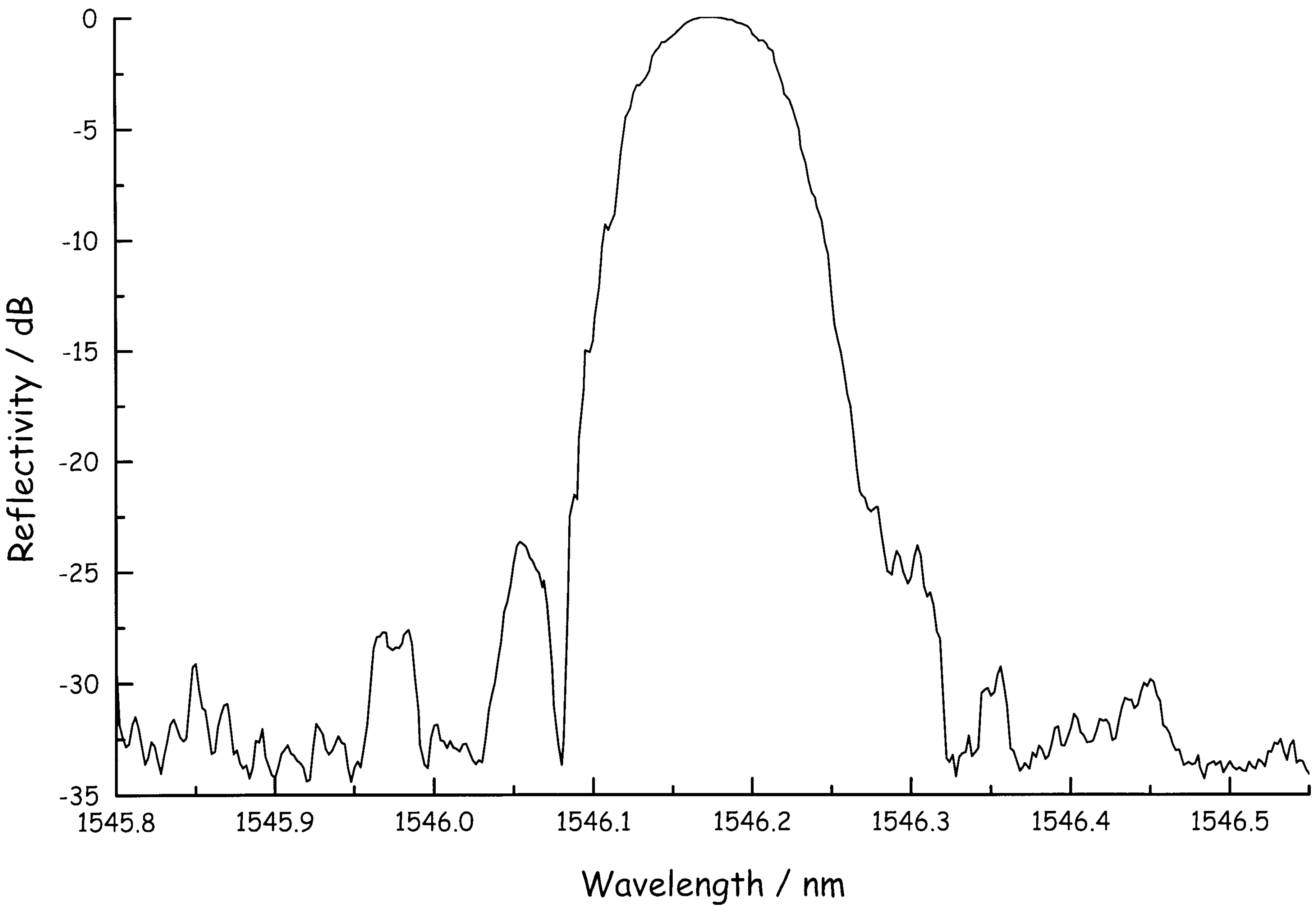
60
40
20
0
1541.5
1542.0
1542.5
1543.0
1543.5
Wavelength / nm



Reflectivity / dB
0
-5
-10
-15
-20
-25
-30
-35
1545.8
1545.9
1546.0
1546.1
1546.2
1546.3
1546.4
1546.5
Wavelength / nm