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40 MHz ALL-FIBRE ACOUSTO-OPTIC FREQUENCY SHIFTER

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Abstract

We report the development of a 40 MHz four-port all-fibre frequency shifter operating at a wavelength of 1.55 μm. The device has a high conversion efficiency, low drive power requirement and is manufactured from standard telecommunications fibre.

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Introduction

A number of different schemes for designing all-fibre acousto-optic frequency shifters have been implemented with varying degrees of success [1-3]. In the most common schemes, an acoustic flexural wave, propagating along a length of fibre, is used to couple light between the guided modes in a dual-mode fibre. Resonant acoustooptic coupling between these modes occurs when the intermodal beat length is equal to the wavelength of the acoustic wave, the coupled-over light being shifted in frequency. More recently, we have reported a four-port fibre frequency shifter incorporating a null taper coupler and operating at 2 MHz [4]. Here we record our success in developing a high frequency version of this device delivering frequency shifts of ~ 40 MHz. This makes feasible the replacement of the conventional fibre-coupled Bragg cell (used in fibre optic systems such as gyroscopes, heterodyned sensors and coherent communications) with a monolithic fibre device offering much lower drive powers and insertion losses of <0.1 dB.

Results

As previously shown, the fibre null coupler that forms the basis of the device can be fabricated as a monolithic four port component using standard telecommunications fibre [4]. Consequently there is no need for mode converters or filters because the device allows direct access to the frequency-shifted component via the coupled output port. In addition to being compatible with any existing network, further advantages of the device include low drive power, low insertion loss and simplicity of construction. Frequency shifts over hundreds of megahertz are feasible simply by reducing the final diameter of the coupler waist [5]. The principles behind the operation of the frequency shifter have been described in Reference 4.

We made a null taper coupler for $\lambda = 1550$ nm using standard telecommunications fibre. A 40 mm length of fibre was initially pretapered from 125 μm to 90 μm. This fibre was then held in parallel contact with an unstretched length of the same fibre and heated and stretched to form a fused coupler. The final coupler waist was 25 mm long with a diameter of approximately 3.7 μm, and had short taper transitions each 31 mm in length. The excess loss of the final device was 0.1 dB and the maximum splitting ratio was 1:900. Light from a 1.55 μm DFB laser was launched into the un-pretapered fiber via a polarisation controller. A co-propagating flexural wave was excited in the plane of the two fibres using a lithium niobate transducer attached to the fibres via a silica horn [4]. An acousto-optic resonance was found at a frequency of 40 MHz. The optical output is plotted in Figure 1 against the peak-to-peak RF drive voltage applied to the transducer; greater than 90 % acousto-optic coupling into the second fibre was possible. The required RF drive power was 3.5 mW. The frequency shift, Figure 2, was measured by interfering the output of the coupled fibre with a coherent wave downshifted by 80 MHz in a standard Bragg cell. The detected beat signal at the output was monitored on an RF spectrum analyser. The frequency shift induced by our device was found to be 40 MHz as expected, with a carrier suppression of about 25 dB. The image sideband was also suppressed by about 25 dB.

Conclusions

We have reported for the first time an all-fibre four port frequency shifter operating at 40 MHz; however, frequency shifts of hundreds of megahertz are possible simply by manufacturing the final device to have a narrower taper waist. The device can be constructed for any wavelength by using the appropriate fibre and, although the conversion efficiency reported for this device is only 90 %, its performance still provides an attractive alternative regarding insertion loss, conversion efficiency and drive power when compared to pig-tailed bulk-optic Bragg cells. Conversion efficiencies approaching 100 % should be possible with improved control of the fabrication conditions, as is the case for other devices made by us which operate at lower frequencies.

Acknowledgements

The ORC is an interdisciplinary research centre funded by the UK EPSRC. T. A. Birks is a Royal Society University Research Fellow.

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Figure Captions

1. Throughput (circles) and coupled (squares) optical output powers of the 40 MHz acousto-optic device versus the pk-pk RF drive voltage across the lithium niobate transducer.

2. RF spectrum of the detected beat signal between the frequency shifted coupled output of the 40 MHz device and light downshifted by 80 MHz in a Bragg cell.

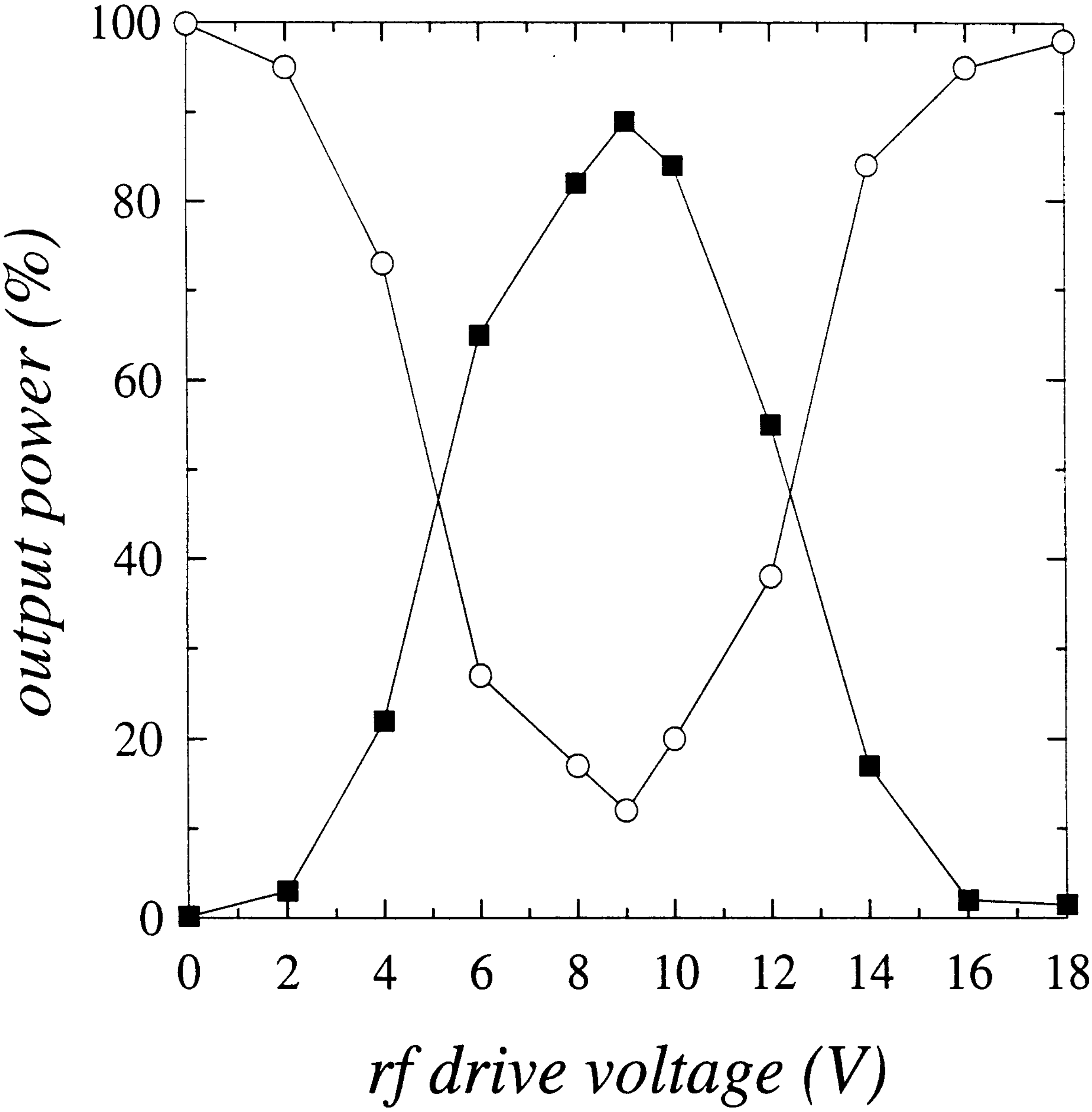
100
80
60
40
20
0
output power (%)
0
2
4
6
8
10
12
14
16
18
rf drive voltage (V)

fig 1.

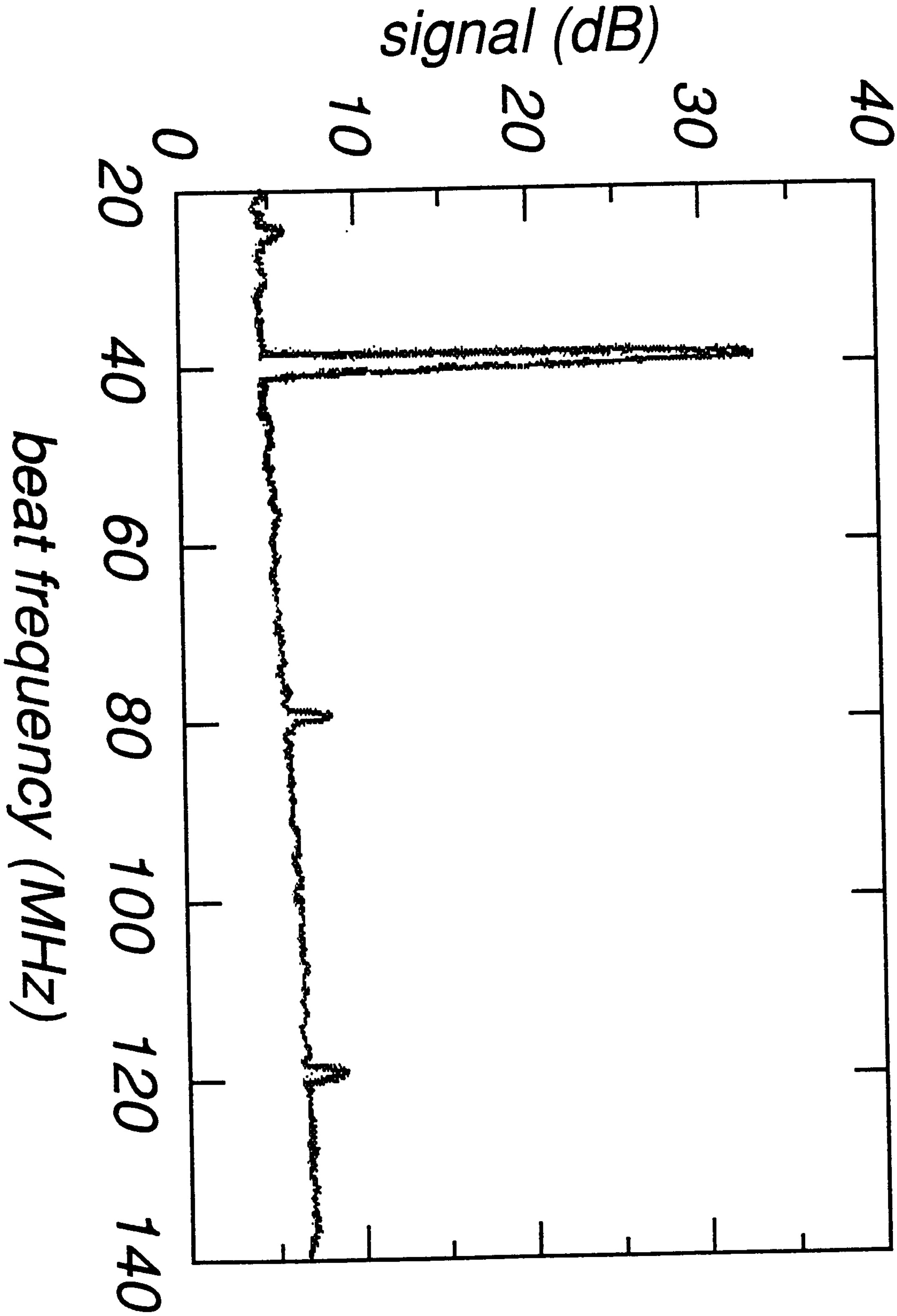
signal (dB)
0
10
20
30
40
20
40
60
80
100
120
140
beat frequency (MHz)

Fig 2