Diffraction efficiency calculation for non-uniform dynamic Bragg gratings in rare earth doped optical fibers for arbitrary contrast

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Abstract: *We studied non-uniform dynamic Bragg gratings recorded by two counter propagating waves in rare earth doped optical fibres.We solved the beam coupling equations taking the first Fourier coefficients of the optical absorption for arbitrary light modulation.*

Theoretical consideration.

Recently [1], a theoretical analysis of two wave mixing has been introduced, in order to support experimental investigations in Erbium-doped fibers. This analysis takes into account the non-uniform distributions of the average optical absorption and the grating amplitude along the fiber. In a medium with saturable absorption the steady-state optical absorption is [1, 2]: $\alpha(z) = \alpha_0 /(1 + (I_0 / I_{SAT})(1 + m\cos Kz))$. Here *m* is the light modulation, I_0 is the average light intensity, I_{SAT} is the characteristic saturation intensity [1]; α_0 is the initial not saturated optical absorption and *K* is the grating vector. We consider a Fourier expansion for $\alpha(z)$ to find the beam coupling equations:

$\frac{\partial A_1}{\partial z} = -\frac{\overline{\alpha(z)}}{2} A_1 - \kappa A_2 ; \frac{\partial A_2}{\partial z} = -\frac{\overline{\alpha(z)}}{2} A_2 - \kappa A_1$, where $\overline{\alpha(z)}$ is the zero Fourier coefficient and κ is coupling constant. This coupling constant is related to the first Fourier coefficient, α_1: $\kappa = \alpha_1/4$. We have for arbitrary *m*:

$$\overline{\alpha(z)} = \left(\frac{\alpha_0}{1+a}\right)\left[1 - \left(\frac{ma}{1+a}\right)^2\right]^{-1/2} ; \ \alpha_1 = \frac{2\alpha_0}{ma}\left\{1 - \left[1 - \left(\frac{ma}{1+a}\right)^2\right]^{-1/2}\right\}.$$ Here $a = I_0 / I_{SAT}$.

And $m(z) = 2\sqrt{I_1 I_2} /(I_1 + I_2)$; where $I_1 = |A_1|^2$ and $I_2 = |A_2|^2$.

We solved numerically the beam coupling equations in a self-consistent way [3]. Then the diffraction efficiency, η, was calculated as function of the normalized distance $\alpha_0 z$ and of $m_0 = m(z=0)$.

Results

For our calculations we used a light wavelength $\lambda = 1532$ nm [4]. In figures 1 to 3 we show our results for η as function of $\alpha_0 z$, for several values of m_0 and a. These results are similar to those reported in [4]. For comparison we also show the results obtained assuming a uniform *m(z)*. We can see a great influence of the non-uniformity of *m(z)*. For a given value

of parameter *a,* the value of *η* is overestimated or underestimated when the uniform *m(z)* approach is used, depending on the value of m_0.

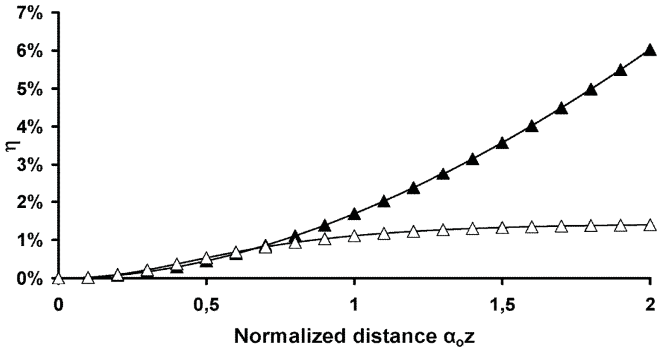

Figure 1: This is *η* as function of normalized distance, $\alpha_0 z$.The value of light modulation is $m_0 = 0.9$ and I_0 / I_{sat} =1.5. The symbol ▲ corresponds to the uniform *m(z)* calculation, and Δ corresponds to results from non-uniform *m(z)* calculation.

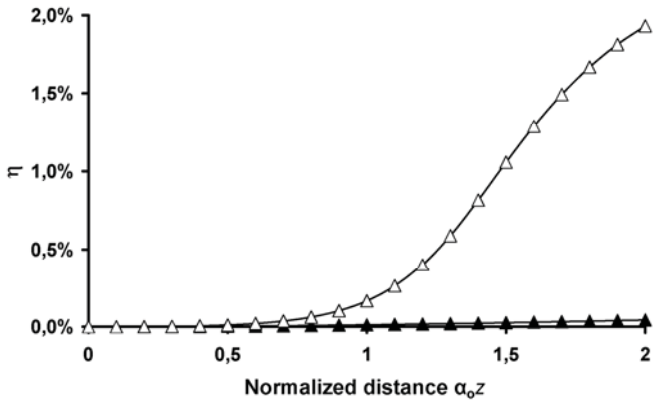

Figure 2: This is *η* as function of normalized distance, $\alpha_0 z$. The value of light modulation is $m_0 = 0.1$ and I_0 / I_{sat} =1.5. The symbol ▲ corresponds to the results using the uniform grating approach, and Δ corresponds to the results obtained using the non-uniform grating approach.

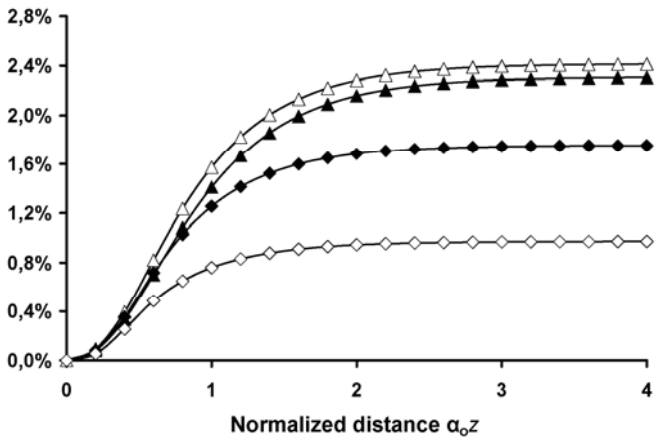

Figure 3: This is *η* as function of normalized distance, $\alpha_0 z$ using the non-uniform grating approach. The value of light modulation is $m_0 = 0.9$. The curves are for different values of normalized average light intensity I_0 / I_{sat} =1.0 (▲), 2.0 (Δ), 4.0 (♦) and 8.0(◊).

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