Effect of Stimulated Raman Scattering (SRS) in WDM system using OptiSystem

Mohit M. Hanumante [1], Dr. Surendra J. Bhosale [2]

[1] *Department of Electrical Engineering, Maharashtra, India*
[2] *Head of Department of Electrical Engineering, Veermata Jijabai Technological Institute, Maharashtra, India*

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Abstract - *Stimulated Raman Scattering (SRS) is one of the most important optical fiber techniques that is used extensively in many scientific fields that can turn optical fibers into broadband Raman amplifiers and tunable Raman lasers. SRS is one of the fundamental nonlinear effects occurs in the optical communication, until recently it was observed as a harmful nonlinear effect because it transfers energy from one channel to neighboring channel which limits the performance of multichannel lightwave system. With the help of optiwave simulation software we are going to build the schematics of the WDM (Wavelength Division Multiplexing) system and by adding the SRS effect, we are going to analyze the results. We are going to analyze the results by varying the power parameter at the input side. So, we observed that at the receiving end the results we get are distorted, due to the existence of the SRS effect in system. we observe that the power gets transfer from one signal to another and after varying the power they get multiplied gradually, can be observed in this paper. This study will help to understand the optiwave software and the effect of SRS on optical communication.*

Key Words: Stimulated Raman Scattering (SRS), WDM (Wavelength Division Multiplexing), optiwave, nonlinear effects, optical fiber communication, Raman tilt.

1. INTRODUCTION

Optical signals are largely affected when light waves transmitted through optical fiber interacts with the materials transmitting them than with each other. This result in nonlinear effects, the strength of which depends on the square (or some higher power) rather than just the amount of light present. With the help of wavelength-division multiplexing (WDM) we are able use the huge bandwidth of the optical fibre due to which it has drawn a lot of attention in broadband optical networks and wireless communication. But when several optical signals are multiplexed, coupling and crosstalk between the multiplexed signals occur as a result of various fibre nonlinear effects, and these phenomena ultimately restrict the performance of WDM networks. Furthermore, optical fibres are the only materials with a particularly low threshold for nonlinear effects. Under the right circumstances, these interactions in WDM produce new waves through a number of non-linear processes, including Stimulated Raman Scattering (SRS), Self-Phase Modulation (SPM), Four Wave Mixing (FWM), and Cross-Phase Modulation (CPM). In a WDM system, these effects limit the maximum power per channel, the maximum bit rate, and the system's optimal efficiency. They also set restrictions on the distance between neighboring wavelength channels. Nonlinearity in optics is an intensity dependent phenomenon which occurs due to change in the refractive index of the medium with optical intensity and inelastic scattering phenomenon.

The Kerr-effect is caused by the refractive index's power dependence. The inelastic scattering phenomena can produce stimulated effects like Stimulated Raman Scattering at high power levels (SRS). Particularly in wavelength-division multiplexing (WDM) systems, these interactions can be a significant drawback in optical communications. Finding output signals with nearly the same quality and quantity as the input signal may be possible with the help of research on non-linearities in optical fibre. But it's a difficult undertaking to study optical fibre communication networks because of the complex interactions between the impairments.

The Raman effect, which Raman first identified in 1928, can be defined quantum mechanically as the scattering by a photon of energy ħωp by a molecule to a lower frequency photon with energy ħωs as the molecule changes to a vibrational state (see fig. 1). The high-energy photon that is also the incident light behaves as a pump, generating frequency-shifted radiation. The energy released by the atom following the collision of the low-energy scattered photons is known as the Stokes wave. The energy of stokes wave is less because the atom absorbed the energy. Some wave called as Anti-stokes are also generated, which has energy higher than the pump stokes ħωa and have high amplitude. It was found in 1962 that intense pump fields can lead to the nonlinear phenomena of SRS, in which the Stokes wave grows quickly within the medium and the majority of the pump energy is transferred to it. Since then, a wide range of molecular media have been used to study SRS extensively. The optical fibres can be converted into broadband Raman amplifiers and adjustable Raman lasers using SRS. In any molecular medium, it can also significantly reduce the performance of multichannel lightwave systems by transferring energy from one channel to neighboring channels (see fig. 2). A tiny fraction of power (usually ~10−6) can be transferred by spontaneous Raman scattering from one optical field to another, whose frequency is downshifted by an amount defined by the medium's vibrational modes.

In this research, our main interest is the study of Stimulated Raman-Scattering (SRS) on fibre optic communication systems. There are many different kinds of simulators that can be used to study the SRS phenomenon, but we chose the most powerful one, called OptiSystem, to evaluate and simulate optical fibre networks and techniques. This simulator has proven to be effective in many areas of planning, testing, and the advancement of optical networking, and it has helped Optiwave expand its features and functionality.

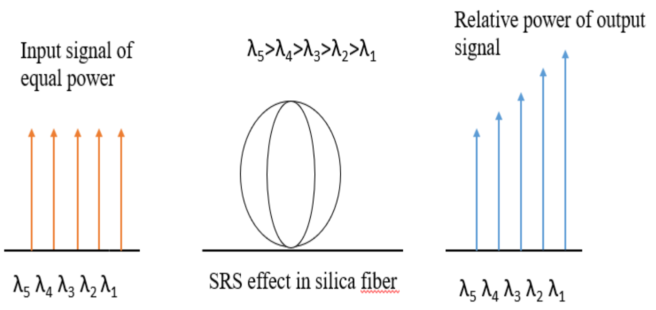
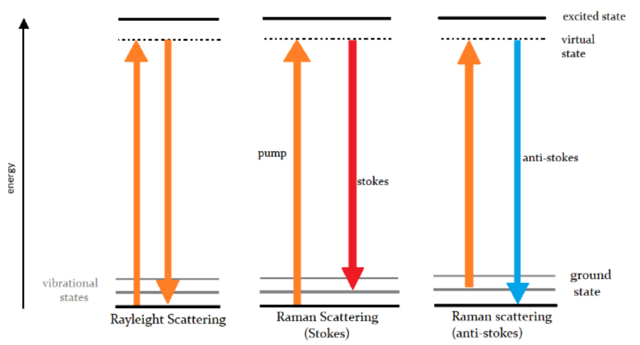


Figure.1 SRS transfer optical power from shorter



Figur.2 band gap representation of stokes and anti-stokes process

2. METHODOLOGY

OptiSystem is an optical communication system simulation software which can be used to design optical communication system and simulate them to determine their performance, given various component parameters. The range we are using is 1609 nm and the difference between each channel will be 10Mhz. For the simulation of SRS effect in WDM system, we required a Continuous wave laser (CW) array. and we have taken 40 ports as outputs from the CW laser array. The other parameters are configured as shown in (fig. 7). All the outputs from the CW laser are given to the WDM Multiplexer (MUX). Then the Multiplexer output which have the same configuration as CW laser array is given into the Non-linear optical fiber.

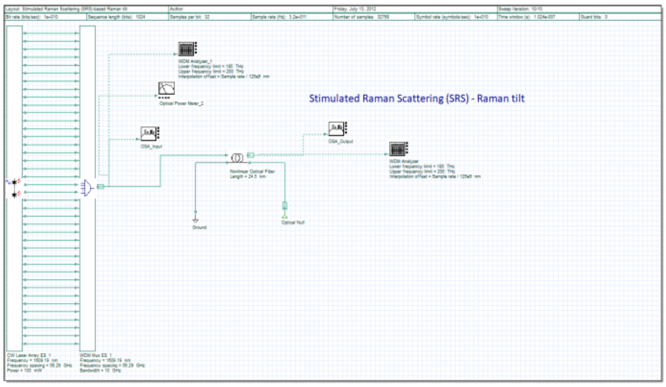


Figure.3 Experiment setup for SRS

In the Nonlinear optical fiber, we need to enable the Raman scattering parameter to add the SRS effect and all the parameters as shown in the figure 5. All the basic layout parameters configuration are shown in figure 6.

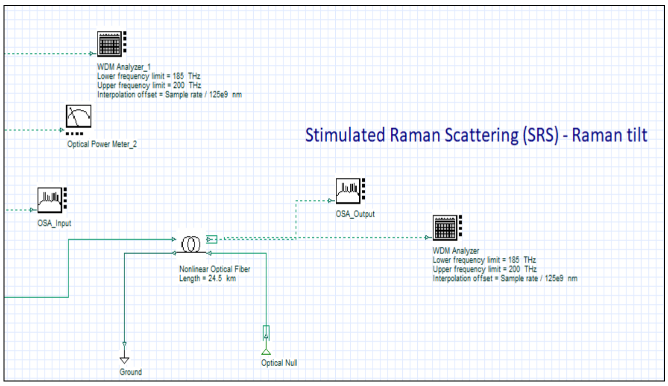
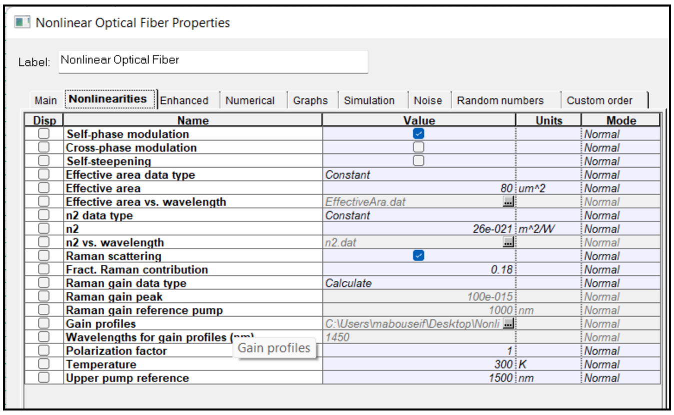


Figure.4 clear view experiment setup for SRS

To observe the effect of SRS on WDM system we are going to keep the power parameter at 2mW. And observe the result.

We are going to analyze how the SRS effect the WDM system when we gradually vary the input power in the WDM system. As we know that in multichannel when SRS is present the energy is transfer from one channel to neighboring channel and a tilt is formed at the output.


Nonlinear Optical Fiber Properties

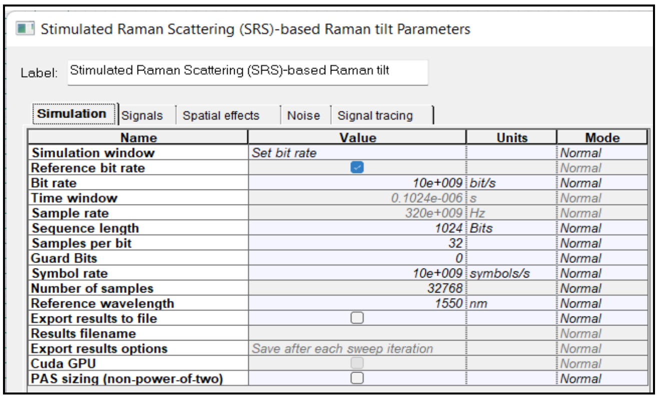
Label: Nonlinear Optical Fiber

Main | Nonlinearities | Enhanced | Numerical | Graphs | Simulation | Noise | Random numbers | Custom order

Disp	Name	Value	Units	Mode
☐	Self-phase modulation	☑		Normal
☐	Cross-phase modulation	☐		Normal
☐	Self-steepening	☐		Normal
☐	Effective area data type	Constant		Normal
☐	Effective area	80	um^2	Normal
☐	Effective area vs. wavelength	EffectiveAra.dat		Normal
☐	n2 data type	Constant		Normal
☐	n2	26e-021	m^2/W	Normal
☐	n2 vs. wavelength	n2.dat		Normal
☐	Raman scattering	☑		Normal
☐	Fract. Raman contribution	0.18		Normal
☐	Raman gain data type	Calculate		Normal
☐	Raman gain peak	100e-015		Normal
☐	Raman gain reference pump	1000	nm	Normal
☐	Gain profiles	C:\Users\mabouseif\Desktop\Nonli		Normal
☐	Wavelengths for gain profiles (nm)	1450		Normal
☐	Polarization factor	1		Normal
☐	Temperature	300	K	Normal
☐	Upper pump reference	1500	nm	Normal

Figure.5 layout parameters of non-linear optical fiber

To observe the result, we have used the Optical Spectrum analyzer (OSA) which helps user to calculate and display optical signals in the frequency domain. OSA has been connected on both input and the output side as shown in fig.9., fig.11., fig.13. fig.15.. Clear view of the output images is shown in fig.10., fig.12., fig.14., fig.16..

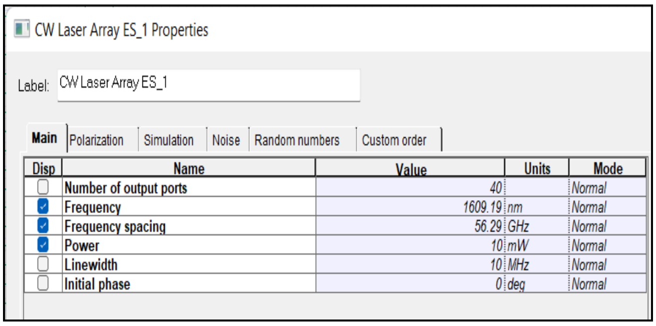

Stimulated Raman Scattering (SRS)-based Raman tilt Parameters

Label: Stimulated Raman Scattering (SRS)-based Raman tilt

Simulation | Signals | Spatial effects | Noise | Signal tracing

Name	Value	Units	Mode
Simulation window	Set bit rate		Normal
Reference bit rate	☑		Normal
Bit rate	10e+009	bit/s	Normal
Time window	0.1024e-006	s	Normal
Sample rate	320e+009	Hz	Normal
Sequence length	1024	Bits	Normal
Samples per bit	32		Normal
Guard Bits	0		Normal
Symbol rate	10e+009	symbols/s	Normal
Number of samples	32768		Normal
Reference wavelength	1550	nm	Normal
Export results to file	☐		Normal
Results filename			Normal
Export results options	Save after each sweep iteration		Normal
Cuda GPU	☐		Normal
PAS sizing (non-power-of-two)	☐		Normal

Figure.6 layout parameter of SRS layout


CW Laser Array ES_1 Properties

Label: CW Laser Array ES_1

Main | Polarization | Simulation | Noise | Random numbers | Custom order

Disp	Name	Value	Units	Mode
☐	Number of output ports	40		Normal
☑	Frequency	1609.19	nm	Normal
☑	Frequency spacing	56.29	GHz	Normal
☑	Power	10	mW	Normal
☐	Linewidth	10	MHz	Normal
☐	Initial phase	0	deg	Normal

Figure.7 layout parameters for CW laser

3. RESULTS AND DISCUSSION

Now we will analyze how the power parameter effects the Raman tilt. For which we will vary the power parameter at the input as 2mw,10mw,25mw,50mw and observe the results.

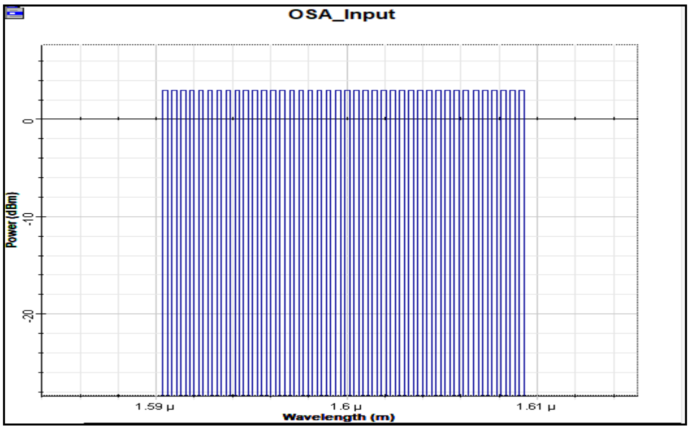


Figure.8 OSA input for 2mW

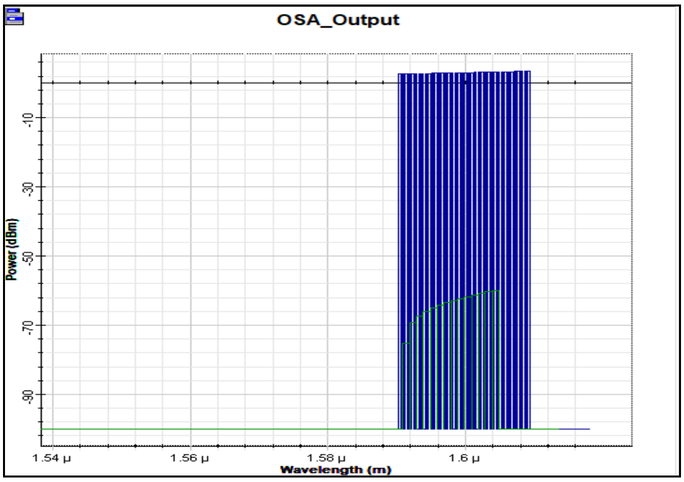


Figure.9 OSA output for 2mW

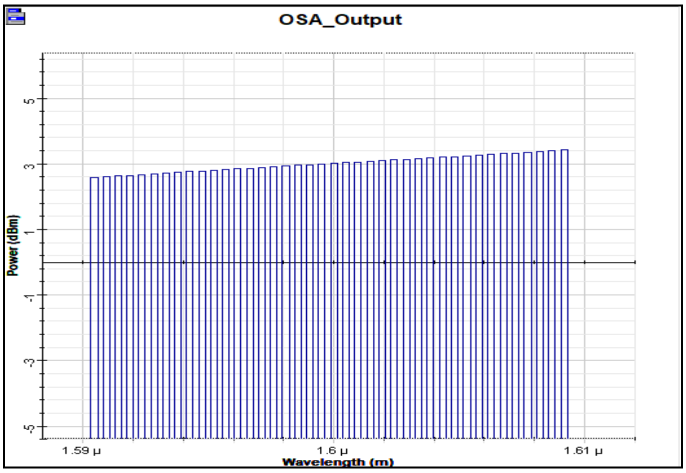


Figure.10 clear view of OSA output for 2mw

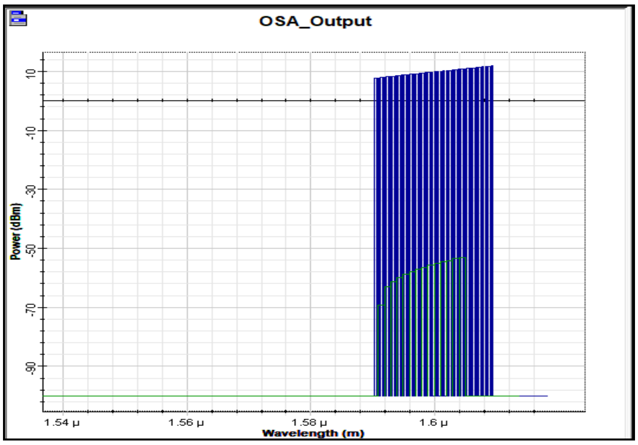


Figure.11 OSA output for 10mW

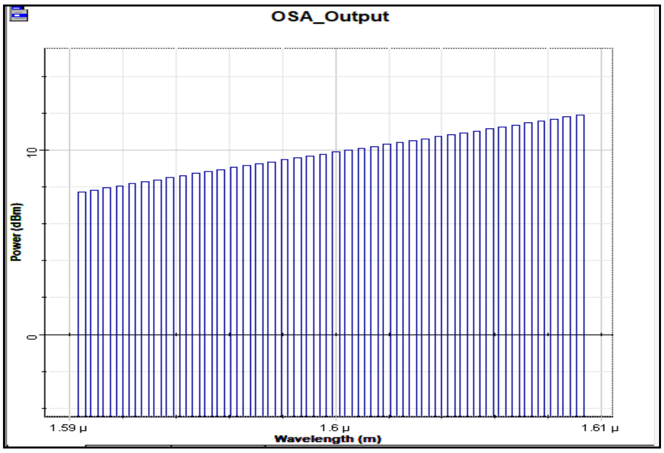


Figure.12 clear view of OSA output for 10mW

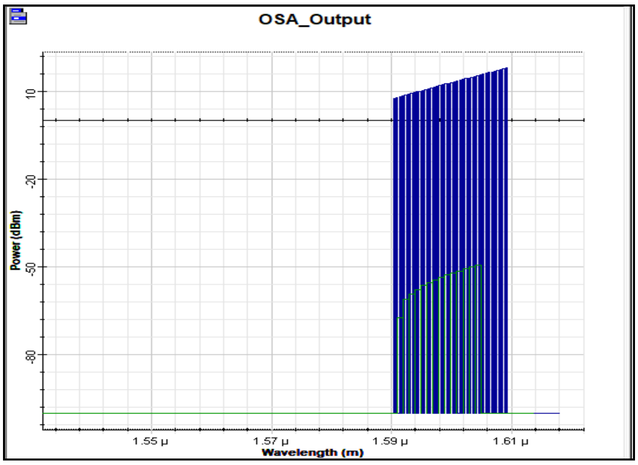


Figure.13 OSA output for 25m

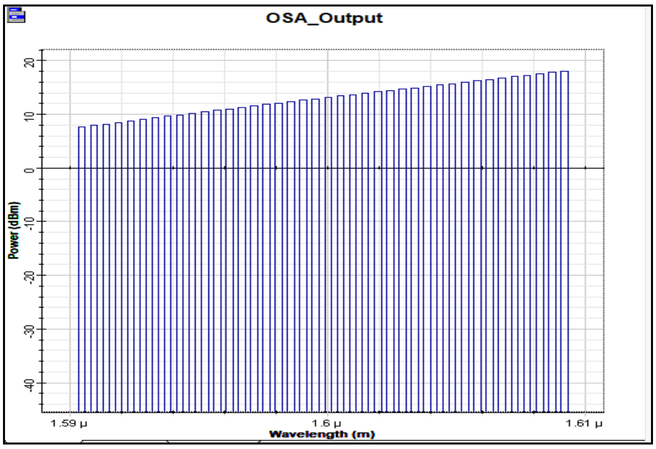


Figure.14 clear view of OSA output for 25mW

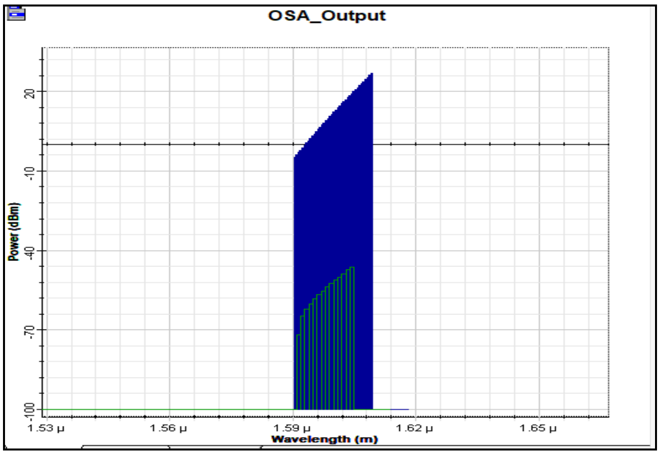


Figure.15 OSA output for 50mW

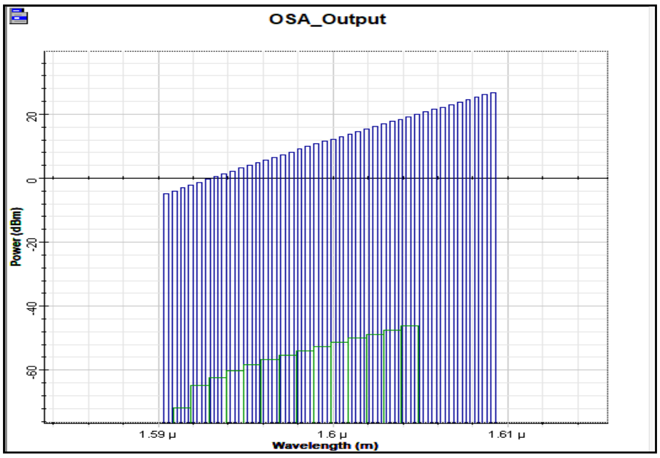


Figure.16 clear view of OSA output for 50mW

We can observe that as we increase the input power the Raman tilt occurred due to the SRS effects gets steepening. And with help of WDM analyzer we see that Optical Signal to Noise Ratio (OSNR) goes on decreasing causing increase in Bit Error Rate (BER).

4. CONCLUSION

This paper focusses on the effects of SRS along with the factors effecting SRS. SRS which power to be transferred from lower wavelength channels to higher wavelength channels was investigated. We found that this optical power tilt or the channel steepening increase with increase in input power, due to which the Bit Error Rate (BER) increase causing distortion in the receiving signal. This effect in WDM system can be minimized by using unequal channel spacing technique and can reduce the unwanted power tilt. So, the input optical power should not be too low or too high. For an ideal system, Power tilt should be zero. Therefore, in order to reduce the Power tilt value, minimum Input power and unequal channel spacing is to be given for the individual channels.

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