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(54) **GAIN FLATTENING WITH NONLINEAR SAGNAC AMPLIFIERS**

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(52) **U.S. Cl.** **359/337.1**; 359/341.1
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(57) **ABSTRACT**

An apparatus and a method provide gain flattening in communications systems wherein a large number of optical signals at different wavelengths must be amplified while maintaining signal power within an acceptable range. Because of differences in gain of typical optical amplifiers as a function of wavelength and input power, the signals at different wavelengths are not amplified by the same amounts. Thus, when amplified multiple times, certain signals tend to become severely attenuated to the point of being no longer useable. The present gain flattening apparatus and method cause signals having higher gain-power products to be attenuated by a greater amount in response to Kerr-induced phase shifting such that after multiple stages of amplification, all the signal powers converge toward a small range of acceptable output powers. The apparatus provides amplification, multiple times, of a series of signals with a plurality of wavelengths covering a very wide spectral range, while maintaining the power of all the signals within a small range. The spread of this signal power range is robust against changes in the signal power, against changes in the number of signals, and, to some degree, against changes in the amplifier's pump power. The apparatus design is also robust against manufacturing changes in the parameters of the apparatus' components. The apparatus and invention are preferably implemented as multiple nonlinear Sagnac amplifiers having erbium-doped fiber amplifiers positioned asymmetrically in an interferometer loop.

21 Claims, 17 Drawing Sheets