UTILIZING SRSC™ TECHNOLOGY IN THE TRANSMISSION OF MULTIPLE FORMATS IN THE CABLE INDUSTRY

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ABSTRACT

The availability of interactive media via cable TV delivery systems is just beginning to grow. There are several limitations to this growth, but none more significant than the current limitations of signal transmission.

SilkRoad's SRSC™ technology will help facilitate the leap in interactive television technology by using a single-wavelength to transport multiple varied signal formats. This not only increases bandwidth, but it also expands accessibility and transmission distance.

This paper describes the basic science of this new technology and how it will lead to multiple-format delivery alternatives.

THE TECHNOLOGY

The Basis of SRSC

SilkRoad Refractive Synchronization Communication™ (SRSC) is an application of photonic physics based on the relativity theory of Einstein and the electromagnetic field equations of Maxwell.[1]

This technology allows "packets" of information (SONET, RF, IP, etc.) to be combined on a single wavelength on a single laser.[2] The signal can then be transmitted with all the advantages that a single wavelength offers:

- Simpler product design
- Fewer lasers and lenses[2]
- Lower lifecycle cost
- Fewer potential points of failure
- More amplification without interference
- More distance before signal regeneration

Despite the use of a single laser, SRSC technology is capable of providing more bandwidth than multiple-wavelength DWDM.

Foundations of SRSC Theory

SilkRoad uses the Mach-Zehnder modulator to achieve the optical tweezers effect, causing dielectric particles (photons) to spiral. The principle behind optical tweezers is that a single beam of tightly focused laser light creates an extremely high electric field gradient in the vicinity of its focus.

Under the influence of this gradient, dielectric particles are drawn into the laser beam. The dielectric particles experience a force directed toward the focus of the beam that resembles a whirlpool effect. They develop an *angular momentum* as they are drawn into the laser, resulting in a corkscrew-like movement along the laser transmission path.

Although the light within the laser has a common source and frequency, the corkscrew patterns may be tight or expanded for different photons based on the time dimensions in which they travel. These variations in the tightness of the corkscrew pattern are known as the photon's angular momentum. Different

1 *This new technology has reformulated Maxwell's equations to solve for wave motion from one medium to another with a non-zero optical index (Maxwell assumes the optical index is zero). In this solution the real part of the optical index (n) and the imaginary part of the optical index (k) in all three orthogonal axes are positionally time dilated in relativistic time.*

2 *SRSC uses a TEM_{00} laser, with no lenses in the transmission equipment.*

levels of angular momentum[3] are identified as *orders of the Laguerre* within the wavelength.[4]

Photons on different orders of the Laguerre may overtake one another, but collisions never occur because, having no mass, multiple photons can occupy the same space at the same time. Figure 1 shows photons traveling in different orders of the Laguerre.

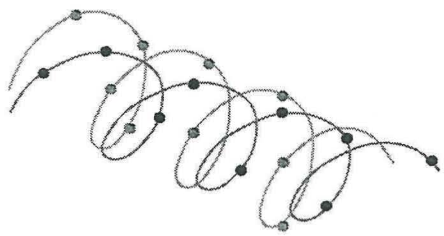

Figure 1 Laguerres in different orders

An orbiting pattern reduces the forward distance photons can travel during a given amount of time, so the degree of stretch in the corkscrew pattern (angular momentum) determines the relative speed at which the photon moves forward.

The highest level of angular momentum is the maximum stretch of the spiral. We refer to this fully stretched pattern as the highest order of the Laguerre. Photons traveling in the highest orders of the Laguerre will travel the greatest distances through fiber-optic cable. At lower levels, the spiral tightens, and the spanning distance declines.

Photons in different Laguerre orders can exist in the same place, but with different relative speeds and different orbits. Each order travels in its own relativistic time.

Since signals of the highest orders of the Laguerre achieve the greatest spanning distance in fiber-optic cable, SRSC uses them as carrier signals for data transmissions (Figure 2). At the receiving end, the Laguerre signals are converted to an electronic signal from which the individual transmissions can be isolated.

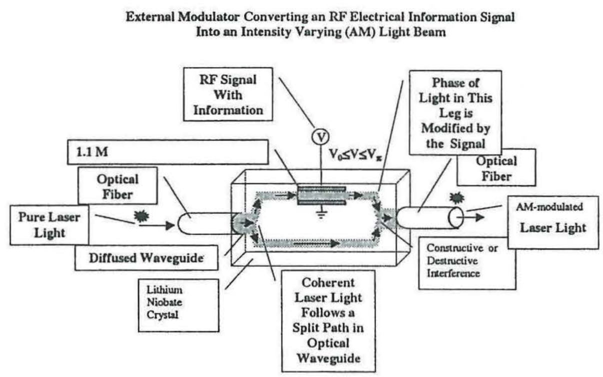

Figure 2 The SRSC Modulation Approach

While SilkRoad uses a broadband RF signal for subcarrier frequency modulation at the electronic level, our laser transceivers use a very narrow spectral bandwidth to transport multiple channels of data. To make an SRSC transmission bi-directional, we shift the ellipsometric phase that is characteristic of the different Laguerre orders.

Optical Refraction

Refraction is the basis of SilkRoad's *Optical Refractive Synchronization*. It is the change of energy, direction, or speed of a light beam that is propagating through a medium when it passes into a second medium.

Snell's Law mathematically represents the angle of both reflected and refracted light traveling from one uniform material through another. It predicts a continuous bending of the light beam and a subsequent change of speed of the light that is proportional to the

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[3] In 1936, Beth first demonstrated the angular momentum that is imparted to an elliptically polarized beam of light. Beth's experiments demonstrated that each Laguerre order had increased angular momentum according to ± **L**• • , where **L** is the Laguerre order. Prior conventional wisdom had been that photons had an angular momentum of ±• • .

[4] The Laguerre Gaussian principle predicts that light photons in different Laguerre orders have different characteristics. Planck's theory suggested that a photon's energy is related to its frequency. Einstein used this theory to explain the photoelectric effect, where the speed of ejected electrons is related not to the intensity of light, but to its frequency. Einstein also discovered that light in a vacuum travels at a consistent speed that is independent of the speed of the observer. In other words, the speed of light is the same for someone traveling at several thousand miles an hour as it is for someone standing still. This led to the theory of relativity within four dimensional space-time.

material's index of refraction, and it allows for calculation of the angle of transmitted light after it passes through the boundary between two media.

Passing a light beam through a crystal changes both the speed of the light beam and its index of refraction. The degree of change is based on the physical properties of the crystal and the polarity of its particles. SRSC modulation splits a signal. It then manipulates the polarity of a crystal on one of the resulting light paths to control the optical refraction. Adjustments in refraction alter the relative phase of the split signals so that when they are reunited they either compliment each other or cancel each other out, producing AM modulation.

Lasers

Lasers are optical resonators or oscillators with mode adjustments[5] that can generate light with different frequencies and characteristics.

The mode options fall into two basic categories:

- **Longitudinal modes** control the spectral characteristics of a laser
- **Transverse modes** control beam divergence, diameter, and energy distribution.

SilkRoad uses a standard laser that is set to TEM_{00} propagation mode (Figure 3) with a patented new distributed feedback (DFB) process. To generate high-level Laguerre-order carrier signals, we use external modulation.

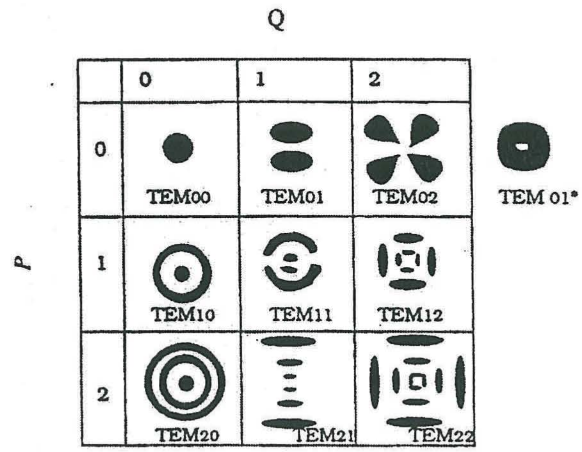

Figure 3 TEM Effects

THE APPLICATION

The simplicity of the SRSC single-laser system fosters high reliability and relatively uncomplicated solutions for add/drop, system redundancy, and other network requirements. SRSC requires less controlling software than competing systems. It also provides more channels than DWDM, faster transmission rates than SONET, and longer distances per hop than other laser-based transmission systems.

SRSC single-wavelength technology helps to control two forms of interference that limit the performance of WDM systems:

- It eliminates four-wave mixing.
- It minimizes the effects of dispersion.

This allows more information to travel further down the fiber, and it minimizes signal degradation, even on fibers that lack the dispersion compensation feature.

5 Unless efforts are made to limit the number of oscillating modes

The Transmission of Multiple Formats

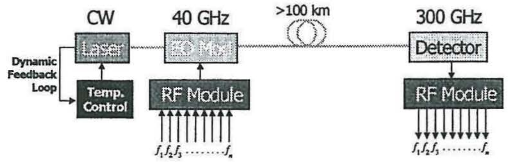

Figure 4 Combining signals on a single wavelength.

Figure 4 shows a single SRSC modulator combining channels with multiple formats on a single laser. The channels can be optical, digital, or analog. Despite these differences in format, the system transmits them as a single signal. Figure 5 shows channel stacking.

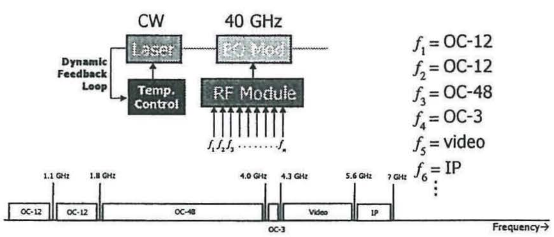

Figure 5 SRSC Simplicity of Stacking Channels

Using this approach, the signal moves in a true optical environment for distribution and management. All signals travel above their baseband in the optical environment and are returned to baseband when utilized at the other end.

This allows the SilkRoad system to use all types of modulation for any and all signal types, including SDH, SONET, RF, HFC, DS and IP.

Bi-Directionality of the Signal

To achieve the bi-directionality required for interactive TV, SRSC switches the optical phase of the signal for each direction. Bi-directional signals of the same wavelength are able to pass through each other without interference due to this difference in phase.

The conversion path on the fiber handles all the information as if it were analog (even if it is shaped in a digital form).

SRSC technology follows this conversion path on the output signal:

Optical → Digital → Analog

Upon return, the signal is converted from:

Analog → Digital → Optical

This full path is taken only if the initial input is optical; otherwise, the path is shortened depending if the signal is digital or analog. Using SRSC, the received signal is the same as the signal sent.

Span Length and Amplification

The SRSC optical signal has a number of advantages over competing technologies in how the signal is transmitted and managed on the fiber. Being a TEM_{00} optical signal, the system is able to send an HFC signal over 100 kms without amplification. When amplification is needed, a standard EDFA device is used to optically amplify the signal. As Figure 6 shows, the limitation on all EDFAs is in the raising of the optical floor (noise level) along with the signal, so the signal must be regenerated after multiple amplifications.

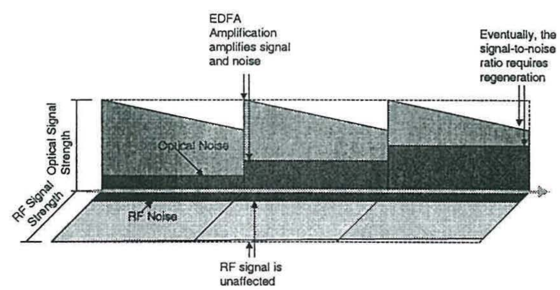

Figure 6 The effect of EDFA Amplification

With no four-wave mixing and fewer dispersion problems, the SRSC signal has less noise to amplify and fewer limitations on the degree to which the signal can be amplified. SRSC also has other means of amplification that can hold down the optical floor and maintain an improved RF signal over a long fiber link. By detecting the signal in RF space and conditioning the signal to be placed on an optical carrier, the optical floor is kept low (Figure 7) as we transport the RF signal needed at the receiving end.

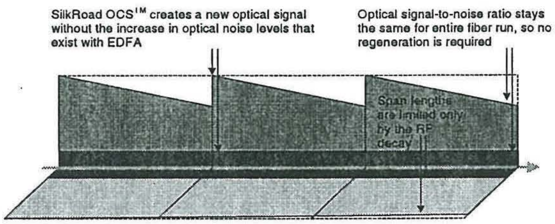

Figure 7 The Effect of SRSC Amplification

This increases the total span lengths and allows the system to maintain and deliver an optical signal matching the highest specifications and standards.

CONCLUSION

SRSC technology is a new approach that offers many benefits for the future of optical transmission signals in all industries.

In cable television, SRSC signals will be able to maintain the specifications for signal integrity over a longer distance and with greater accessibility.

About the author:

THOMAS W. MYERS is the Director of Engineering at SilkRoad, Inc. With a BS in Industrial Engineering and an MS in Electrical Engineering, Mr. Myers has instructed engineering courses at several colleges and universities. He has won several major engineering awards, including an Emmy for technical achievement, has several published books, and has been awarded four patents.