UltraVOA Array Application Note

Transient Suppression and Channel Identification and Control

1. Introduction

It is a well-established practice for communications systems designers to use variable optical attenuators (VOAs) for controlling optical power levels in front of receivers, amplifiers and for channel equalization. Over the last several years there has been a variety of electrically actuated opto-mechanical VOAs commercialized for such uses. Many important new applications for VOAs are emerging, especially for metro and access networks. Many of these applications require high speed VOAs, eliminating the slow, electrically actuated opto-mechanical VOAs from consideration. To address these new network requirements, Kotura has introduced a line of very high-speed UltraVOA^{TM} Arrays that have no such speed limitations. The UltraVOA^{TM} Arrays are in production and are qualified to Telcordia GR-1221, GR-1209, and the applicable portions of GR-468.

Kotura's UltraVOA^{TM} Arrays are solid-state, electrically controlled variable optical attenuators based on silicon opto-electronic integrated circuit (SOEIC) technology. SOEIC technology derives from and is fully compatible with standard CMOS technology, therefore it is the platform of choice for creating optical components that are compact, easy to manufacture, and can combine multiple functions in the same package. Figure 1 shows a comparison of a CMOS wafer and a SOEIC wafer: the key difference with SOEIC is the addition of waveguides for the propagation of optical signals; other features are the same. It is expected that the SOEIC technology platform will put optical components on similar performance and cost curves as those of electronic ICs. Kotura's SOEIC technology is described in detail in a paper available from Kotura titled "Silicon Opto-Electronic Integrated Circuits: Bringing the Excellence of Silicon into Optical Communications".

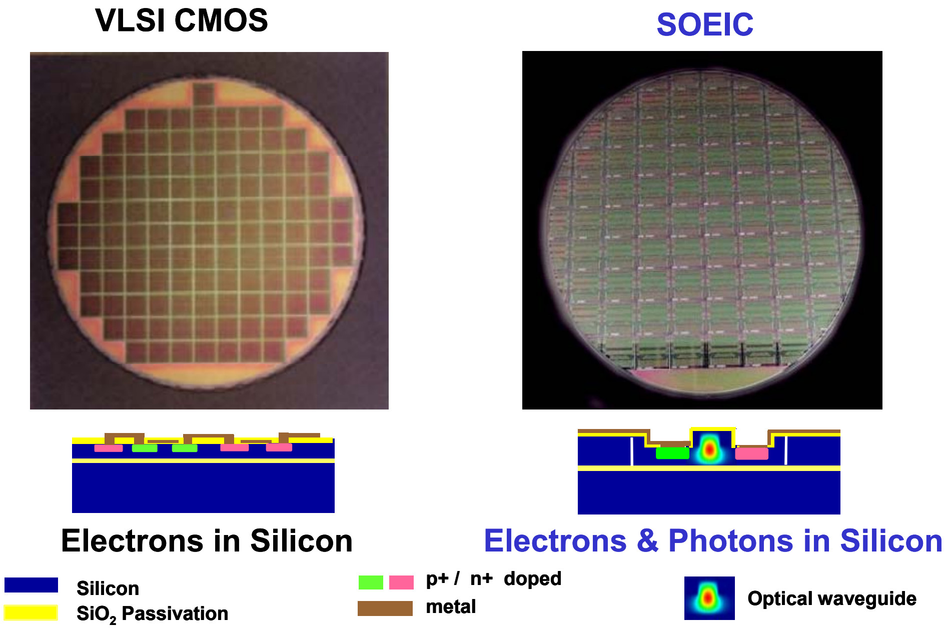


Figure 1. Comparison of CMOS and SOEIC Wafers

The UltraVOA™ Arrays make use of single-mode optical waveguides along with p-i-n diodes integrated on the same substrate to create up to eight independently variable VOAs in a 14-pin butterfly package with a footprint smaller than half of that of a business card. The structure in Figure 2 represents one of up to eight channels of a Kotura UltraVOA™ Array. The devices rely on the fast free carrier absorption effect to control optical power through an in-line waveguide. As shown in the diagram, free carriers across the p-i-n diode absorb photons propagating in the waveguide; the higher the current across the diode, the greater the attenuation. Because the attenuation mechanism is temperature dependent, the UltraVOA Arrays also feature a built-in thermistor and thermo-electric cooler (TEC). Kotura's UltraVOA™ Arrays exhibit best-in-class characteristics of sub-microsecond response time, wide attenuation range, low PDL, and compact footprint.

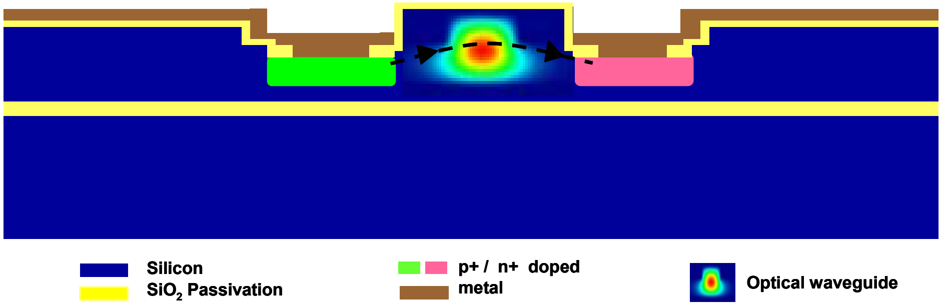
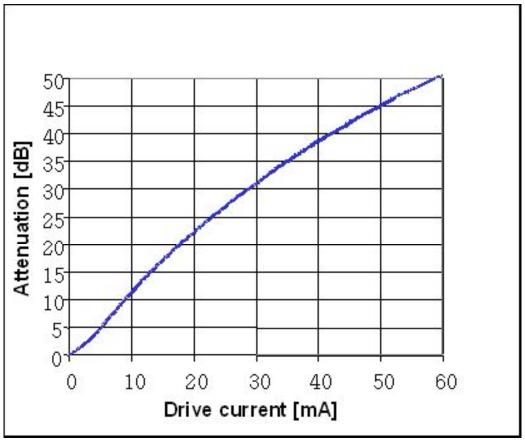


Figure 2. SOEIC VOA Detail

Kotura's UltraVOA™ Arrays are very simple to control because of the monotonic response of attenuation vs drive current as depicted in Figure 3. This characteristic response is inherent to the physics of the devices and is very repeatable. The curves in Figure 4 are from measurements of response time; the red curve shows a 10 dB change in attenuation as observed at a photodetector, and the blue curve is the drive voltage.



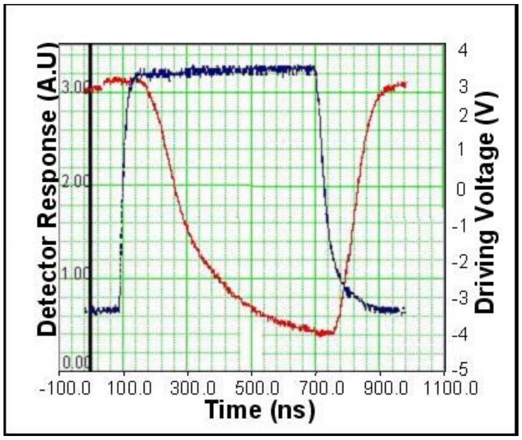


Figure 3. Attenuation vs. Drive Current

Figure 4. Response Time

The sub-microsecond response time of Kotura's UltraVOA™ Arrays gives systems designers the unprecedented ability to use VOAs for high-speed transient suppression as well as for subcarrier modulation which can be used to add wavelength and channel identification markers thereby enabling additional functionality in the optical control plane. These novel applications, which can only be implemented with very fast VOAs are described in the remainder of this note.

2. Transient Suppression

Faults, including fiber cuts and network element failures that require traffic re-routes can cause optical power transients that must be controlled in order to avoid component damage and ensure error-free transmission. However, these fault events are only part of the story in a transport network where even normal operations could lead to transients[1]. Optical transport networks are becoming increasingly complex topologically in both long haul and metro segments of the network. Wavelengths can be terminated, or switched at any point in the network, giving rise to unpredictable optical power transients that can propagate unchecked, even if the optical amplifiers have some level of transient control. The likelihood of generating optical power transients will only increase as service providers increase the deployment of optical transport systems closer to the customer. For example, the action of dropping some preemptible services in order to accommodate higher service level agreements (SLAs) can require switching or rerouting some wavelengths, which in turn can lead to optical transients. A closed loop control circuit that takes advantage of the sub-microsecond response time of Kotura's UltraVOA™ arrays is a straightforward and elegant solution to suppressing these transients that would otherwise affect network performance[2].

It has been shown that a control loop using VOAs with microsecond response time can effectively suppress transients as large as 12 dB for a 120 microsecond pulse as, for example, could be caused by a signal reroute due to a fiber cut[2]. Figure 5 shows the block-diagram level of a typical transient suppression circuit. Similar analog control techniques have been in use for decades and the constituent components, including logarithmic amplifiers and voltage comparators are well understood. However, it is only with the availability of high-speed VOAs that these methods can be applied for optical power transient suppression since the response time of the control circuit and of the VOA must be fast compared to the offending transient[2,3].

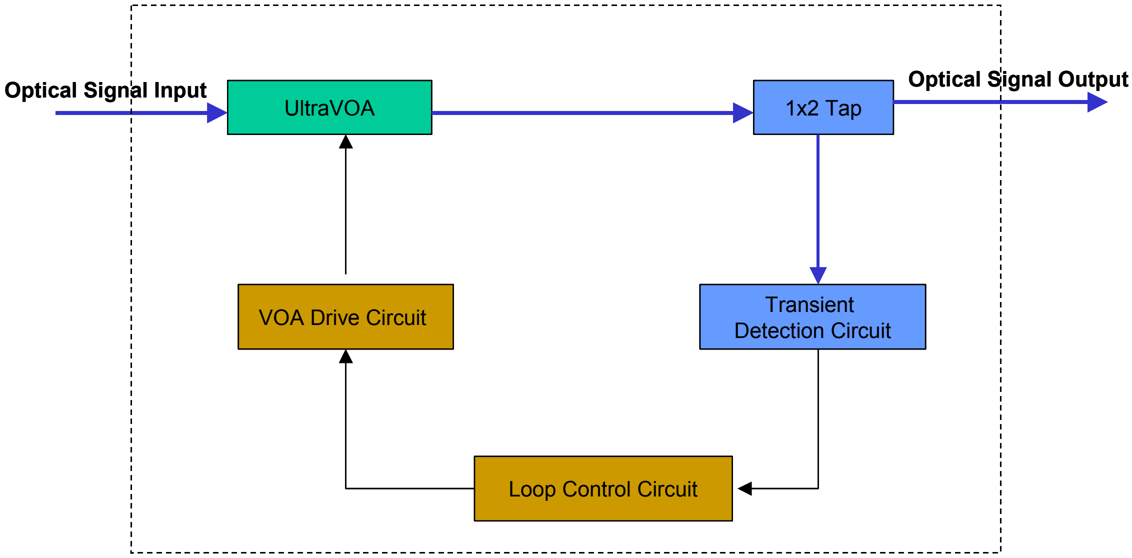


Figure 5. Block Diagram of Transient Suppression Circuit

It is even possible to further simplify the transient suppression circuit by integrating the 1x2 tap and the photodetector for the transient detection circuit into a single component.

3. Wavelength Identification and Control

Another function that is important in making optical transport more manageable in metro core and edge networks is transparent optical channel identification. The ability to identify optical channels regardless of underlying protocols and payloads, paves the way towards implementation of the optical control plane. With legacy transport systems, the only way to identify optical channels is to either read the overhead bytes of the SONET frames, or in the case of native IP, to read the actual packets being transmitted. In both instances, this functionality requires the additional cost and complexity of performing optical-to-electrical-to-optical (OEO) conversions. Transparent optical channel identification enables a wide range of very useful functions including automated flow-through provisioning of wavelengths, enhanced performance monitoring, and automated topology discovery. Once all network elements can take advantage of transparent optical channel identification, full fault management, configuration management, accounting management, provisioning, and security (FCAPS) capability can be implemented at the wavelength level in a practical, cost-effective manner.

Because of the sub-microsecond response time of Kotura's UltraVOA^{TM} Arrays, the devices can be modulated with analog signals with digitally encoded subcarriers that will uniquely identify a particular wavelength. As shown in Figure 6, for example, an UltraVOA^{TM} placed at the output of a transmitter to control the optical power level for that specific wavelength can simultaneously be modulated with an analog signal that will uniquely mark that wavelength throughout the network. In the simplified diagram of Figure 6, a VOA driver and closed loop power control circuit communicate with the Element Management System (EMS) and Network Management System (NMS) in order to control optical power level and superimpose wavelength identification and other supervisory information for each wavelength.

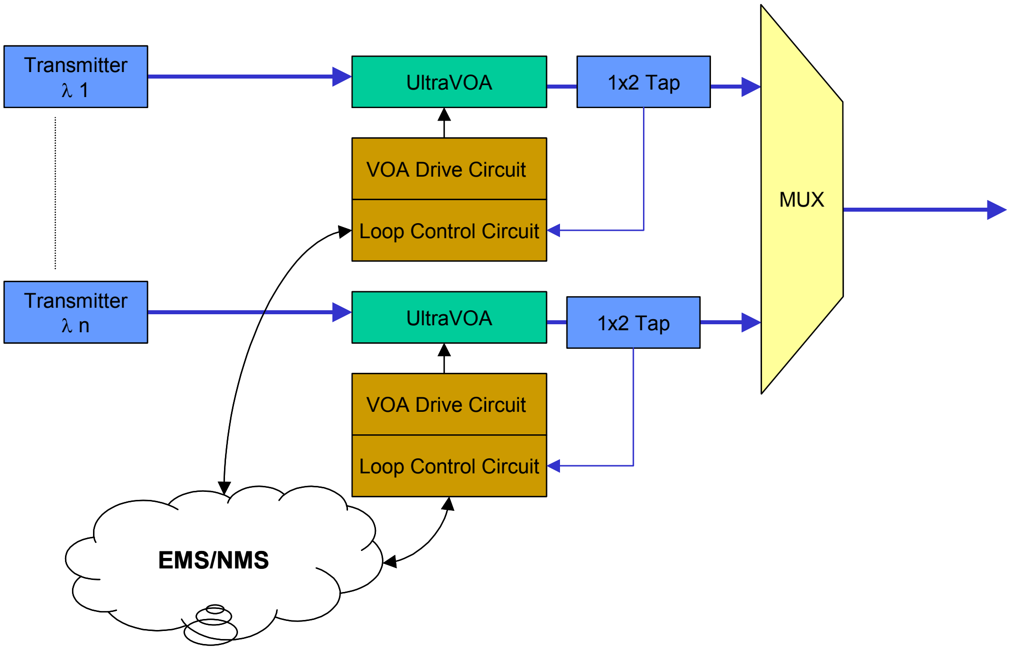


Figure 6. UltraVOA^{TM} for Optical Power Level Control and Channel Identification

It has been shown that as long as the modulation index is sufficiently small there will be virtually no impact on signal integrity, even with a subcarrier with a center frequency on the order of 10 MHz, which is achievable with a VOA response time of less than a microsecond[4]. Therefore, it is possible to add a significant amount of information for identification and control without any regard to the underlying protocols or formats being transported. The electronics required to encode and decode the identification and control information are relatively simple, low speed and low cost devices. Thus, using a component that would have been in the system anyway for optical power level control, a system designer can add wavelength identification and supervisory information thereby greatly enhancing network functionality.

4. Summary

Optical components such as Kotura's UltraVOA^{TM} Arrays are important tools for systems designers of advanced communications equipment. As optical transport systems become increasingly complex and are being deployed ever closer to the customer, new functionalities are required for transient suppression and wavelength identification and control. These new functionalities are readily achievable with Kotura's UltraVOA^{TM} Arrays because of their sub-microsecond response time. Based on Kotura's SOEIC technology, the UltraVOA^{TM} Arrays offer advantages similar to CMOS chips; compact footprint, a path towards more integration, and robust manufacturing. With the availability of low-cost, solid state UltraVOA^{TM} Arrays, systems designers are able to build transport systems that are more robust, and easier to manage.

5. References (we need complete references here)

1. P. Lundquist, M. Levesque, J. Morrier, D. Zaccarin, "Optical Transients in Cascaded EDFA's: Effects on Transmission System Performance".
2. P. Lundquist, M. Levesque, D. Smith, D. Zaccarin, "Suppression of Optical Transients in Dynamic DWDM Transmission Systems".
3. S. Cohen, "Novel VOAs provide more speed and utility", Laser Focus World, Nov 2002
4. T. E. Darcie, P. F. Driessen, M. Osusky, W. Lin, "Optical Network Control Overlay Using Silicon VOA Arrays".

Appendix - UltraVOA^{TM} Interface and Control

1. Introduction

Kotura's UltraVOA Arrays are commercially available as 4-channel or 8-channel modules. Both configurations share the same 14-pin butterfly package with diagonally offset holes for mounting and ribbon fiber pigtails for the optical ports. The modules also feature a built-in thermistor and thermo-electric cooler (TEC) for temperature monitoring and control since the free carrier absorption mechanism for attenuation is temperature dependent.

Please note the following:

1. **Pin-outs and dimensions described here are for reference only; always use an up-to-date Customer Drawing of the relevant UltraVOA^{TM} module for design purposes.**
2. **Always follow standard ESD and fiber handling procedures when working with the UltraVOA^{TM} Arrays and other optoelectronic modules.**
3. **Tampering with the module such as opening the lid will void all warranty on the product.**

2. Mechanical Dimensions and Mounting

A perspective view of the 4- and 8- channel VOA Module is shown in Figure 2.1. The module has 14 electrical pins in a butterfly configuration. Pin 1 is located near the triangle symbol, **Δ**.

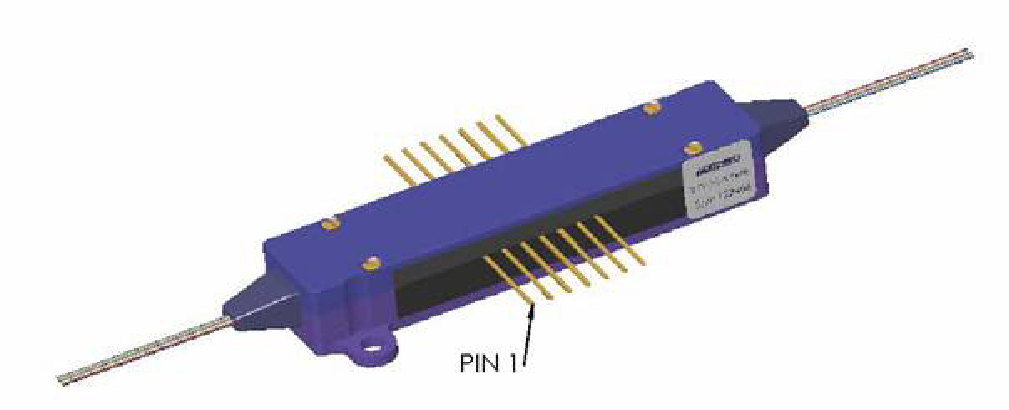


Figure 2.1. Three-Dimensional View of a UltraVOA^{TM} Module.

There are two mounting tabs on a diagonal; fiber ribbons exit the module at either end. Heat-sink options are available if desired. Figure 2 illustrates approximate dimensions. Consult the Customer Drawing for specified dimensions and mounting details.

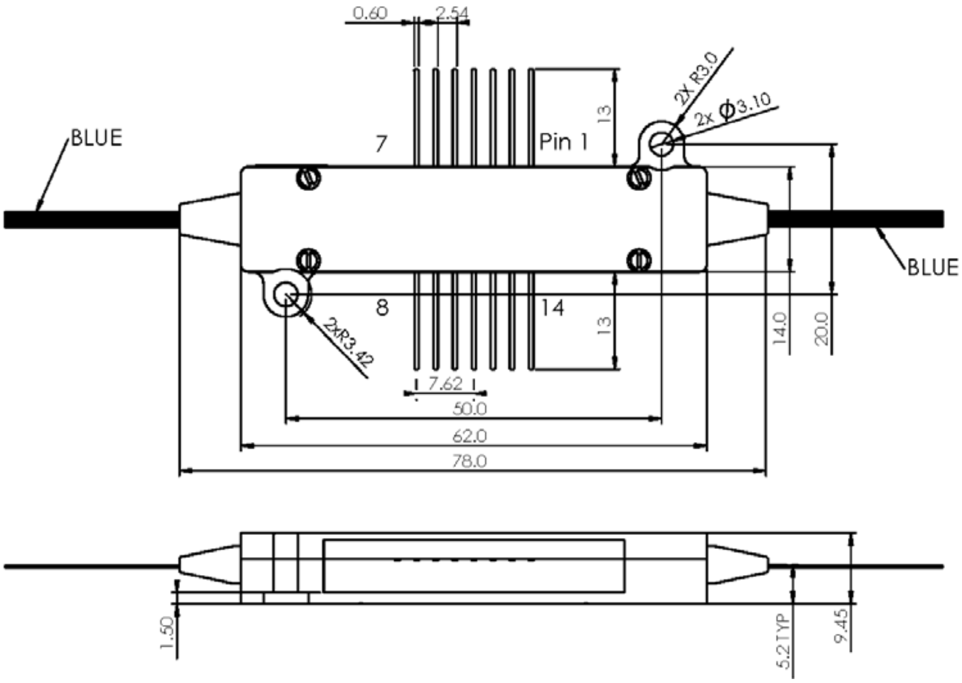


Figure 2.2. Typical Dimensions [mm] of the UltraVOA^{TM} Module.

3. Fiber Ports

The fiber color assignments are shown in Table 3.1.

Color near Pin 1 or 14	Color near Pin 7 or 8	4-Channel UltraVOA^{TM}	8-Channel UltraVOA^{TM}
Blue	Black	Not used	1
Orange	Red	Not used	2
Green	White	1	3
Brown	Slate	2	4
Slate	Brown	3	5
White	Green	4	6
Red	Orange	Not used	7
Black	Blue	Not used	8

Table 3.1: Fiber Color Code for 4 and 8- Channel UltraVOA^{TM} Module.

4. Electrical Pin-Out

Electrical pin assignments are described in Table 4.1 below. Attenuation is controlled in the Kotura UltraVOA^{TM} Arrays by supplying a current to the anode-cathode pair for each channel. The 8-Channel UltraVOA^{TM} Array uses one common anode for all eight channels. Each module also has two pins for the TEC and two pins for the thermistor as described in the table. Please note that UltraVOA^{TM} Arrays can be supplied in custom configurations, therefore it is important to check the relevant Customer Drawing to validate pin assignments and, in particular, the polarity of the TEC and VOAs.

	4-Channel		8-Channel	
Pin no	**Name**	**Description**	**Name**	**Description**
1	TEC-	TEC- driver	TEC-	TEC- driver
2	Ch3+	Channel 3 Anode	AN	Anode (Common)
3	Ch4+	Channel 4 Anode	N/C	Not Connected
4	N/C	Not Connected	CA8	Channel 8 Cathode
5	N/C	Not Connected	CA7	Channel 7 Cathode
6	Ch4-	Channel 4 Cathode	CA6	Channel 6 Cathode
7	Ch3-	Channel 3 Cathode	CA5	Channel 5 Cathode
8	Ch2-	Channel 2 Cathode	CA4	Channel 4 Cathode
9	Ch1-	Channel 1 Cathode	CA3	Channel 3 Cathode
10	TH	Thermistor	CA2	Channel 2 Cathode
11	TH	Thermistor	CA1	Channel 1 Cathode
12	Ch1+	Channel 1 Anode	TH	Thermistor
13	Ch2+	Channel 2 Anode	TH	Thermistor
14	TEC+	TEC+ driver	TEC+	TEC+ driver

Table 4.1 Pin Description for 4- and 8- Channel UltraVOA™ Module.

5. VOA Maximum Electrical Characteristics

Parameter	Value	Units
Maximum Applied Current – Forward Bias	60	mA
Maximum Reverse Voltage	20	V (DC)

6. Thermo-Electric Cooler Maximum Electrical Characteristics

Parameter	Units	Value
Maximum Applied Current (Imax)	A	1.5
Maximum Applied Voltage (Vmax)	V(DC)	3.75
Maximum Power (Qmax)	W	4.65
Maximum Delta Temperature (Dtmax)	°C	65

7. Thermistor Specifications

A Z-curve, 10k Ohm thermistor is placed adjacent to the silicon VOA to monitor the VOA temperature. Refer to http://www.thermistor.com/catalog/qtmb.pdf for technical information on a typical thermistor. The Steinhart-Hart Coefficients curves and resistance values can be located at http://www.thermistor.com/mathcad.cfm. The data for the Z curve can be found at http://www.thermistor.com/catalog/curves-z-y-t-w.pdf.

8. Additional Assistance

For help or information on any aspect of the module, please contact Kotura at:

Phone: 626-236-4500
Email: sales@kotura.com