from the two outer wavelengths, the subcarrier is extracted and used for downconverting the wavelength channels located at 1542 nm and ture signals that are used to detect their phase
sion.
the incoming data over several bits according
time in the electronic domain by shifting
the 1542 nm and 1548 nm wavelength channels.

Figure 2 shows the setup of the RF detection module. After high pass filtering the signal from the two outer wavelengths, the subcarrier is extracted and used for downconverting the pilot tones. These tones generate two quadra-
ture signals that are used to detect their phase
differential and accurately determine the time
skew.

We simultaneously transmit 1-Gbit/s NRZ data and the SCM pilot tones in the two outer wavelength channels located at 1542 nm and 1548 nm. The unsynchronized and synchro-
nized received channels are shown in Fig. 3(a) after propagation through 6.5 and 34.1 km of fiber (i.e., fine) and 3.3 km of fiber for

CTuT1 Fig. 3. (a) Received unsynchronized and synchronized 1 Gbit/s bit streams after trans-
novation through 6.5 km and 34.1 km of fiber for the 1542 nm and 1548 nm wavelength channels. (b) BER measurements for (1) baseline with max. data voltage swing, (2) baseline with data and SCM pilot tones transmitted together, (3) after 6.5 km SMF and (4) after 34.1 km SMF transmission.

CTuT2 4:45 pm
Self-assembled micro-scanner fabricated by surface-micromachining technology
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Optical scanners are used in a wide variety of applications such as printing, quality inspection, confocal microscopy, data storage, precision pattern generation, display, and medical imaging. Scanning micromirrors fabricated using the micromachining technology is very attractive because of smaller size, lighter mass, and lower power consumption. Earlier works on micromachined scanning mirrors have been re-
alized by either bulk or surface micromachining technology. Surface-micromachined optical scanners are particularly interesting because they can be integrated with other micro-mechanical and/or optoelectronic devices. However, the scan angles of current surface-micromachined scanners are limited by the displacement of in-plane actuators such as comb drive and bimorph micro-actuators. Torsion mirrors, with angular gap closing actuators, on the other hand, have larger rotation angles. In this paper, we report on the performance of an out-of-plane tilt torsion mirror that can be self-assembled by the integrated scratch drive actuator (SDA). This device is compact, light-
weight, and can be mass-produced at poten-
tially very low cost.

The scanning electron micrograph (SEM) of the tilt torsion mirror is shown in Fig. 1. The scanner consists of a torsion mirror, a polysil-
one frame and, a SDA actuator. The torsion mirror is suspended by a polysilicon frame that is self-assembled by the integrated SDA. It is designed to rotate up to 12° towards the sub-
strate before it is pulled in by the electrostatic
force. The 680-nm-thick low-stress LPCVD
silicon nitride layer is deposited on the sub-
strate as an electrical isolation layer. One ad-
vantage of this design is that the substrate can be used as the electrode to increase reliability, as compared with the previous design. The principle of operation is illustrated in Fig. 2. The micromirror, originally lying on the sub-
strate after fabrication, is assembled by apply-
voltage pulses to the SDA actuator. Then, the actuator moves forward to push up the polysilicon frame that is connected to the mi-
cromirror. Therefore, the initial angle between the mirror and the substrate can be controlled
by manipulating the traveling distance of the SDA. The mirror is 300 μm wide, 250 μm tall and 1.5 μm thick. The torsion beam is 912 μm long, 2 μm wide and 1.5 μm thick. The scan angle versus the DC bias voltage is plotted in Fig. 3(a). The torsion mirror has a maximum pull-in angle of 12° at the voltage of 110 V. The pull-in voltage depends on the initial angle of the polysilicon frame, as shown in Fig. 3(b).

In summary, a novel out-of-plane self-
assembled tilt torsion mirror made by surface-micromachining technology has been successfully demonstrated. An optical scan range of 24° and a resonant frequency of 0.5 kHz have been achieved. Its applications include optical scanners, switches, and on-chip optical choppers for monolithic micro-optical instruments.


CTuT3 5:00 pm

Polarization-independent waveguide modulators using 1.57 m-strained InGaAs/InGaAsP quantum wells

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The performance of multiple quantum well (MQW) electroabsorption (EA) waveguide modulators based on the Quantum Confined Stark Effect (QCSE) shows considerable promise due to the low drive voltage, enhanced exciton absorption, and high-speed operation. MQW photonic communication systems do not preserve the signal polarization, so it is essential that MQW devices that are used operate independently of the input polarization. Since the transverse magnetic (TM) absorption is due to the first light-hole (LH1) subband to electron transition and transverse electric (TE) absorption is mainly from the first heavy-hole (HH1) subband to electron transition, tensile strain has been used in MQW devices to restore the degeneracy of the two levels. However, this degeneracy is destroyed upon application of a reverse bias since the shift in the ground state energy due to the QCSE is proportional to the effective mass $m^*$.

$$C_{m*} E^2 / h^2,$$

where $L$ is the length of the QW, and $F$ is the applied electric field. Taken as a whole, it can be seen from Eq. 1 that an equivalent Stark shift for both the HH1 and LH1 can be obtained provided the product of the effective mass and the fourth power of the well width is designed to be equal. Our approach uses a unique quantum well design that incorporates two thin highly tensile strained GaAs-strain layers in order to provide separate confinement, and effective well widths denoted by $L_{HH1}$ and $L_{LH1}$ for the LH1 and HH1 wavefunctions respectively, as illustrated in Fig. 1. This design maintains the degeneracy of the LH1 and HH1 energy levels, for polarization independent transmission, for potentially larger values of the electric field as compared to other approaches. The QW design consisted of a five-period, 90 Å In$_{0.5}$Ga$_{0.5}$As quantum well and 100 Å Ga$_{0.22}$In$_{0.22}$As/Ga$_{0.33}$P$_{0.67}$ barrier. The peak in the PL spectrum was at 1.57 μm for both TE and TM. The 3 monolayer GaAs-strain layers are located 20 Å from the In$_{0.5}$Ga$_{0.5}$As quantum well edge as illustrated in Fig. 1. It was necessary to etch past the active region in order to ensure equal confinement for both TE and TM. A methane-based reactive ion etching process was used to define 2.3 m wide ridges deep-etched to a total depth of 2.9 m, 0.7 μm past the active region.

The transmission measurements as a function of reverse bias were performed using a tunable external cavity laser over the wavelength range 1.610–1.630 μm as shown in Fig. 2. The solid (open) symbols are for TE (TM) respectively. At zero volts reverse bias, the difference between TE and TM is within 1 dB over a 20 nm range. A 3 dB difference in the polarization dependence is maintained over a 2 V range. The cut-on/off ratio was as large as 18 dB for 2 V at 1630 nm. The deep etch process was essential to achieving polarization independence since for narrow ridge devices, etched only to a depth of 1.2 μm, the TE transmission was smaller than TM by 6 dB.

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Ultrafast all-optical gating with compact semiconductor devices requires materials with high absorption modulation, sub-picosecond response times, and low absorption in the fully saturated state (low nonsaturable losses). While the time response in low-temperature grown (LT) semiconductors, as e.g. GaAs, has been intensively investigated, only limited information is available about the strength of the modulation. For the first time, we correlate the time response with the strength of the modulation in as-grown and annealed LT-GaAs. The modulation is very weak in as-grown LT-GaAs with sub-picosecond response times. We demonstrate that annealing substantially increases the modulation and preserves a fast, sub-picosecond response, yielding a superior material for ultrafast all-optical gating. A qualitative model is presented which relates the material properties to the defect structure and the defect-related optical transitions in LT-GaAs. Based on this model, for the first time, guidelines are obtained for controlled defect