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# All-optical TOAD based new binary sequence generator

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**Abstract** Spread-spectrum communication, with its inherent interference attenuation capability, has over the years become an increasingly popular technique for use in many different systems. In multiuser environment, Gold sequences are an important class of sequences that allow construction of long sequences. To achieve this goal, a modified Gold code generator in all-optical domain using semiconductor optical amplifier based terahertz optical asymmetric demultiplexer (TOAD) is explored in this paper. All-optical Gold code generator circuit realization is TOAD based D flip-flop and exclusive-OR logic gates in a configuration analogous to the standard electronic setup, with properties similar to that of both Gold and Kasami sequences. It is compatible with a multichannel direct sequence spread spectrum system. Numerical simulation confirmed the circuit's feasibility and performance in terms of the choice of the critical parameters. However, the proposed sequence generator circuit is more complex than the existing Gold sequence generator, but it is less complex than the Kasami sequence and has performance better than both.

**Keywords** Terahertz optical asymmetric demultiplexer · R–S and D-flip-flop · m-Sequence · Gold code · Pseudorandom binary new sequence

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## 1 Introduction

Pseudorandom binary sequence (PRBS) generators are commonly used in digital electronics primarily in applications mainly dealing with digital communication and test pattern generation. The pseudo-noise (PN) sequence finds application in Multichannel Direct Sequence Spread Spectrum and Frequency Hopping Spread Spectrum Signaling in which the multiplexed signals of different channels are coded with PN sequences. A PN sequence is a periodic binary sequence with a noise-like waveform generated using a linear feedback shift register and its main advantages are anti-jamming, multipath protection, multiple access, message privacy, and identification. The most widely used PN sequence is the maximum-length shift register sequence or m-sequence.

Code division multiple access (CDMA) schemes have been seemed a significant multiple access schemes in the third-generation (3G) and future broadband wireless systems. Despite the improvement of photonic integration, still the design and operation principle of the all-optical Gold code generator circuit need improvement. Gold sequences are constructed by taking a pair of specially selected m-sequences. Terahertz optical asymmetric demultiplexer (TOAD) and semiconductor optical amplifier (SOA)-assisted gate effectively combine fast switching time and benefits of reasonable noise figure. Code division multiplexing (CDM) provides an alternative to the traditional methods of frequency division multiplexing (FDM) and time-division multiplexing (TDM). It does not require the bandwidth allocation of FDM nor the time synchronization needed in TDM. Rather, users of a common channel are permitted to access simultaneously assignment of mutually (near) orthogonal spreading codes. In an ideal CDM system, the cross-correlation among the spreading codes of different users should be zero i.e. codes sequences would be mutually orthogonal. For this ideal condition to be realized, it requires that cross-correlation function between the spreading codes assigned to any two users of the system would be zero for all cyclic shifts. However, ordinary pseudo noise (PN) sequences do not satisfy this requirement because of their relatively poor cross-correlation properties.

The need for PN sequences is not limited to the realm of electronics only but also extends to optics as-well, as efforts continue to overcome the electronic bottlenecks and to exploit fully the advantages of fiber communication without need of optical-electrical-optical (OEO) conversions. Unfortunately, the ordinary m-sequence implementation cannot be directly applied in the optical domain due to their relatively poor cross-correlation properties. As a remedy for this shortcoming, a special class of PN sequences called Gold sequences (codes) may be used. Gold sequences are constructed by using a pair of specially selected m-sequences to form a new modified sequence which is denoted as a Gold sequence (Wornell 1995; Popovic 1999; Maity et al. 2009). An all-optical pseudo random binary sequence (PRBS) generator has been reported which makes use of a terahertz optical asymmetric demultiplexer (TOAD) and semiconductor optical amplifier (SOA)-assisted gate to effectively combine fast switching time and has the benefits of reasonable noise figure (Zoiros et al. 2011; Sokoloff et al. 1993; Zhang et al. 2003). More specifically, this realization would develop ultrahigh speed diagnostic and measurement equipment with comparative performance over their electronic counterparts.

In general, SOA assisted TOAD switches are operationally versatile and are characterized by a fast switching time, low power consumption, high repetition rate, low latency, a noise and jitter tolerance, compactness, high non-linear properties and thermal stability (Maity et al. 2009; Roy and Gayen 2007; Roy et al. 2008). All these properties enable their efficient exploitation in a real ultra-high speed optical communications environment

(Mandal and Maity 2014a, b). In addition, they can be exploited in more complex all-optical signal processing applications without significantly changing their fundamental architecture. From the last century, TOAD based gate has taken an important role in optical communication and information processing (Zoiros et al. 2007; Mandal et al. 2015a, b). SOA-based TOAD switches can obtain demultiplexing rates of Tb/s (Sokoloff et al. 1993).

In this work, we design an all-optical code generator using serially interconnected discrete TOAD based D flip-flops in a configuration analogous to the standard electronic setup in order to generate modified Gold sequences. This modified Gold Sequence (MGS) generator allows for the generation of more sequences with a given input as well as reduced circuit complexity compared to existing designs. The objective of this work is to propose MGSs in all optical domains in an affordable, controllable and realistic manner. The superiority of the proposed scheme is verified by simulation results and compared with recently reported methods using electronic circuits.

This paper is organized as follows: Sect. 2 describes briefly the basic operation of TOAD based m-sequence generators, D flip-flops based a maximal length Pseudo-noise sequence (m-sequence) and Gold codes. Section 3 presents the proposed MGS (code) generator. Using Matlab-9, Sect. 4 shows the simulation results. The paper concludes with a discussion of future scope in Sect. 5.

## 2 Background

### 2.1 Principle of TOAD based Switch and D flip-flop

The key component of our optical implementation is the TOAD switch. The TOAD consists of a loop mirror with an additional intra-loop 2 × 2 (ideally 50:50) coupler as shown in Fig. 1. The loop contains a control pulse (CP) and a nonlinear element (NLE) that is offset from the loop's midpoint by a distance Δx.

The electric field at the output ports can be expressed as:

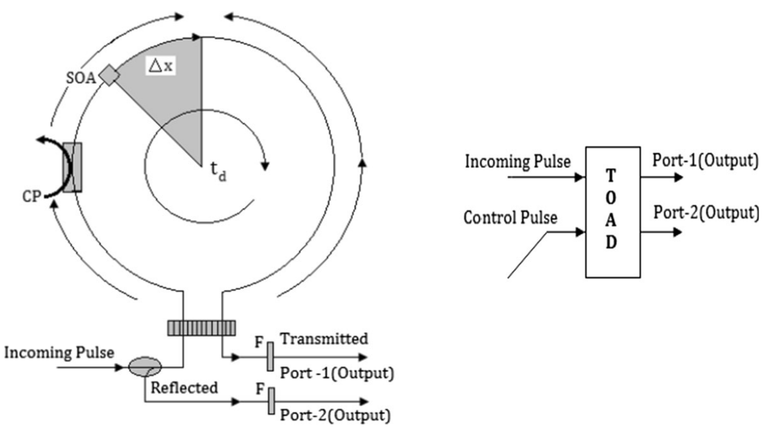


**Fig. 1** TOAD based optical switch (*left*) and light path diagram (*right*)

$$\vec{E}_{0,1}(t) = \vec{E}_i(t - t_d)e^{-j\omega t_d}\left[d^2 g_{cw}(t - t_d) - k^2 g_{ccw}(t - t_d)\right] \tag{1}$$

$$\vec{E}_{0,2}(t) = jdk\vec{E}_i(t - t_d)e^{-j\omega t_d}[g_{cw}(t - t_d) - g_{ccw}(t - t_d)] \tag{2}$$

where, $E_i(t)$ is the input electric field at the input port at time t, $t_d$ is the pulse round trip time within the loop, k (d) specifies the cross (through) coupling coefficient and $g_{cw}$ ($g_{ccw}$) represent the complex time dependent field gain for the clockwise (counter-clockwise) propagating light. The output power can thus be expressed as:

$$P_{0,1}(t) = \frac{P_i(t - t_d)}{4}\left\{G_{cw}(t) + G_{ccw}(t) - 2\sqrt{G_{cw}(t).G_{ccw}(t).\cos(\Delta\phi)}\right\} \tag{3}$$

$$P_{0,2}(t) = (dk)^2\frac{P_i(t - t_d)}{4}\left\{G_{cw}(t) + G_{ccw}(t) + 2\sqrt{G_{cw}(t).G_{ccw}(t).\cos(\Delta\phi)}\right\} \tag{4}$$

In the above equations, $G_{cw}(t) = 2\ d^4\ g^2_{cw}(t)$ ($G_{ccw}(t) = 2\ k^4\ g^2_{ccw}(t)$) is the power gain in the clockwise (counter-clockwise) direction and $\Delta\phi = -\ \alpha/2\ln\ (G_{cw}/G_{ccw})$.

For an ideal 50:50 coupler, $d^2 = k^2 = 1/2$. In the absence of the control pulse (CP), the data signal (Incoming pulse, IP) enters the fiber loop. While the cw and ccw pulses pass through the SOA at different times, they experience the same unsaturated amplifier gain ($G_{cw} = G_{ccw} = G_o$) before recombining at the input coupler. In other words, $\Delta\phi = 0$, resulting in $P_{o,1} = 0$ and $P_{o,2} = G_o\ P_i$. When a control pulse is injected into the loop it saturates the SOA changing its index of refraction resulting in the counter-propagating pulses experiencing different gain saturation profiles, resulting in a non-zero output on port-1. (Note that in this analysis the presence of a light pulse is '1' and the absence is interpreted as '0') The resulting truth table is shown in Table 1. As can be seen in Table 1, the output of port-1 corresponds to a logical IP AND CP and the output of port-2 corresponds to IP AND NOT CP operation.

We can now use combined TOAD switches to build an optical 1-bit binary memory unit (S–R latch). As seen in Fig. 2a, two TOADs are used for the S–R latch. The addition of a third TOAD allows for an all-optical implementation of a D flip-flop (Fig. 2b). Considering first the operation of the latch, the 'S' and 'R' binary inputs, connected via a wavelength converter (WC) and an erbium doped fiber amplifier (EDFA), function as control pulses (CP) for TOAD switches $S_1$ and $S_2$ respectively. In our configuration, a constant light source (CLS) is used to provide the incoming pulse (IP) to the two TOADs allowing them to function as binary NOT gates. The output of the TOADs is taken from the reflected ports (port-2 in Fig. 1) providing $\bar{Q}_{n+1}$ and $Q_{n+1}$. Part of the outputs $Q_{n+1}$ and $\bar{Q}_{n+1}$ are fed back to S and R inputs, respectively, with the help of a beam splitter (BS) and a beam combiner (BC).

The outputs for different input combinations are as follows: when S = 0 and R = 1, $S_2$ receives light, so $Q_{n+1} = 0$. As it is connected to input 'S', then $CP_1 = 0$ and so $S_1$

**Table 1** Truth table of TOAD

| Incoming pulse | Control pulse | Port-1 | Port-2 |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 |
| 1 | 0 | 0 | 1 |
| 1 | 1 | 1 | 0 |

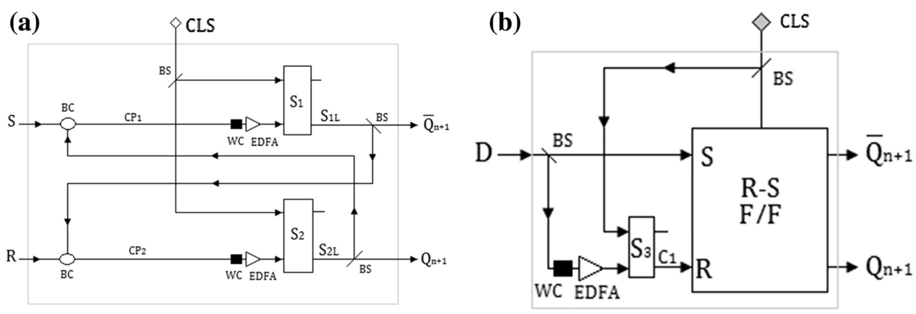


**Fig. 2** All optical binary, **a** S–R latch and **b** D flip-flop

receives no light, which means that $\bar{Q}_{n+1} = 1$. Since $Q_{n+1}$ and $\bar{Q}_{n+1}$ are connected to the S and R inputs, respectively, if both the signals are withdrawn, i.e. S = R = 0, then $Q_{n+1}$ and $\bar{Q}_{n+1}$ retain the same value. The case when S = 1 and R = 0 is analogous to the previous case with output levels switched. Finally, when S = R = 1, both $S_1$ and $S_2$ switches receive both the incoming and control signal, so the outputs of both TOADs receive no light, i.e. $Q_{n+1} = \bar{Q}_{n+1} = 0$. The stored data is cleared from memory and this state is "forbidden".

A D flip-flop can be constructed by S–R latch and a binary NOT gate. An all-optical form of D flip-flop can be realized by adding a single TOAD ($S_3$) between the input and R port of the RS latch, as shown in Fig. 2b, to ensure that the "forbidden" state (S = R = 1) never happens. Here light from the single input (D) is split by a BS with part of the light going directly to the S input of the RS latch and part connected via a WC and EDFA to the additional TOAD ($S_3$). As with the TOADs in the RS-latch, the incoming signal of switch $S_3$ is taken from a CLS. Operationally, if light is absent (D = 0), then S = 0 and R = $C_1$ = 1 (light on) and $Q_{n+1} = 0$ and $\bar{Q}_{n+1} = 1$. Conversely if input D receives a light pulse, S = 1 (light on) and R = $C_1$ = 0 (light off) and $Q_{n+1} = 1$ and $\bar{Q}_{n+1} = 0$.

## 2.2 Pseudo-noise sequence (m-sequence) generator

Based on D flip-flops a maximal length Pseudo-noise sequence (m-sequence) can be generated incorporating a linear feedback shift register and an exclusive (XOR) gate. A simple block diagram of m-sequence generator circuit having 3 D flip-flops and a single XOR is shown in Fig. 3. From the basic properties of the m-sequence (Gayen and Roy

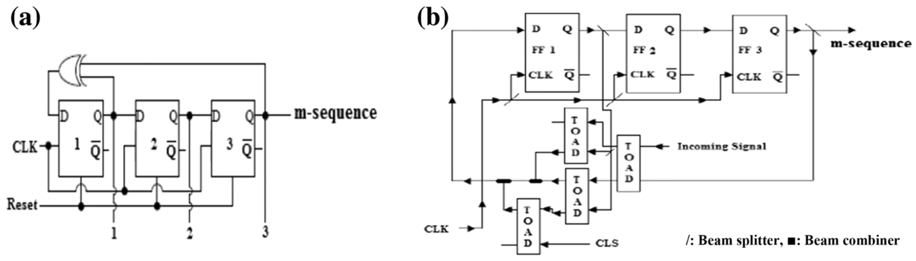


**Fig. 3** M-sequence generator, **a** eElectronic, **b** optical

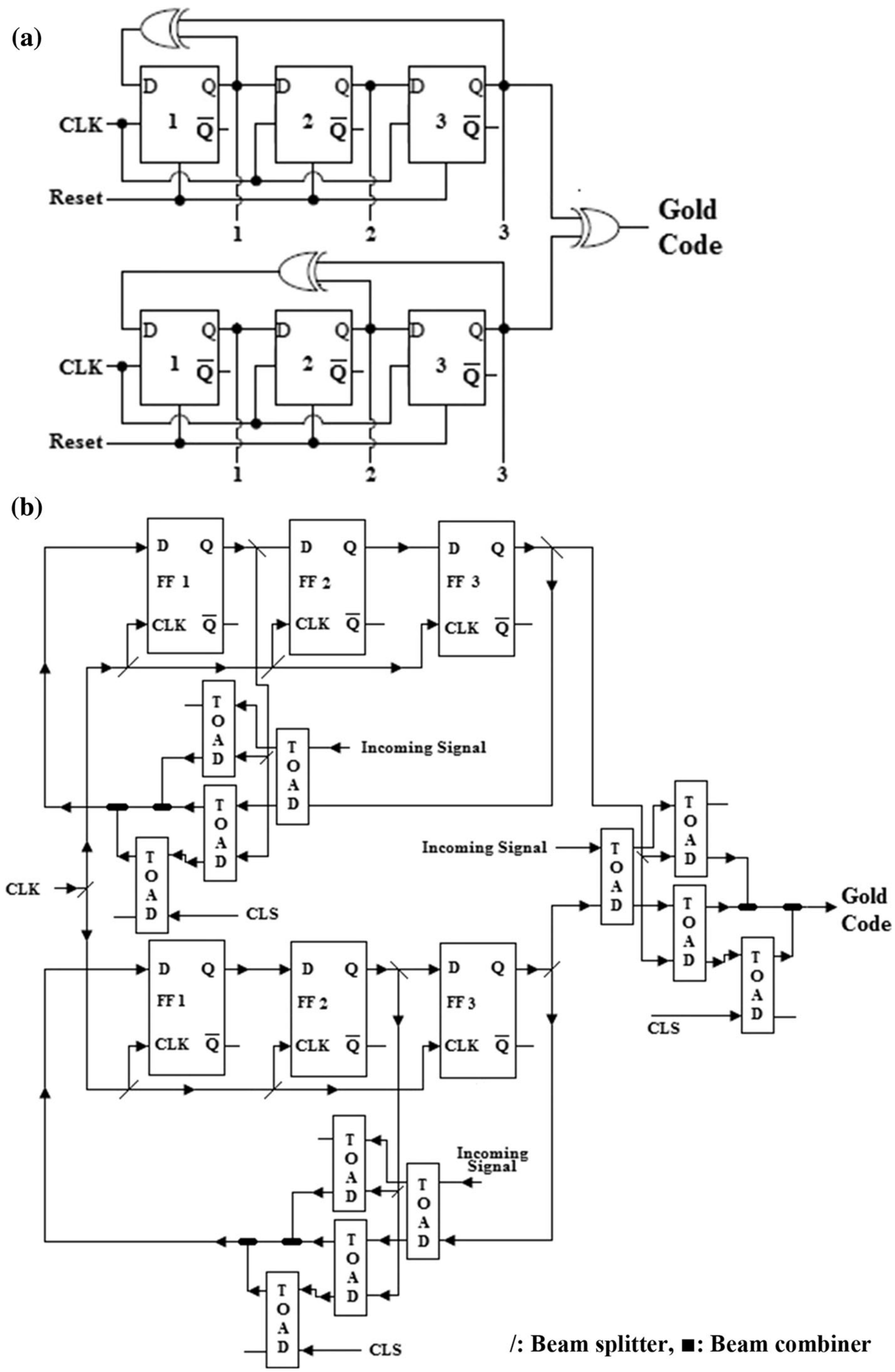


**Fig. 4** Gold code generator, **a** electronic, **b** optical

2008), we get the length (N) of 7. Here, the all-optical XOR gate is implemented with a SOA-based interferometer with two logical inputs. The TOADs are connected in the tree architecture (Roy et al. 2008), the primitive polynomial used here is of degree $m = 3$ and is $g(x) = x^3 + x^2 + 1$. After simulation we get the corresponding set of 3 m-sequences of period 7. Since each D flip-flop requires 3 TOADs and the XOR gate needs 4 TOADs, the complete all-optical m-sequence realization requires 13 TOADs.

## 2.3 Gold sequence generator

As mentioned in the introduction, Gold codes are achieved by the XOR-ing (modulo-2 adding) of two m-sequences of the same length. The code sequences are added chip by chip by synchronous clocking. A gold code can be generated by flip-flops in series according to the desired order while feeding back to the first one the logical outcome of the XOR operation. An $m = 3$ degree gold code generator is shown in Fig. 4a with the electronic implementation and Fig. 4b the optical schematic. Every change in phase position between the two generated m-sequences causes a new sequence to be generated (Chattopadhyay et al. 2013). When specially selected m-sequences, also called preferred m-sequences are used, the generated code is called the Gold code (Maity and Maity 2012). Let $g_1(x)$ and $g_2(x)$ be a preferred pair of primitive polynomials of degree 'n' whose corresponding shift registers generate maximum-length sequences of period $2^n - 1$ and whose cross correlation function has a magnitude less than or equal to $2^{(n+1)/2} + 1$ for n odd or $2^{(n+2)/2} + 1$ for n even. Then the shift register corresponding to the product polynomial $g_1(x)\ g_2(x)$ will generate $2^n + 1$ different sequence with each sequence having a period of $2^n - 1$. Gold's theorem then states that the cross correlation between any pair of such sequences will also meet the preceding conditions. This code can be generated using D flip-flops and XOR gates. TOADs are inserted in the tree architecture-based XOR gate reported in (Roy and Gayen 2007; Maity and Maity 2012). Summing up, a completely optical gold code realization requires 30 TOADs. As with the m-sequence, the length of gold sequence is $N = 2^3 - 1 = 7$. As for the m-sequence, the primitive polynomial used here is of degree $m = 3$. For the preferred pair the two polynomials are $g_1(x) = x^3 + x^2 + 1$ and $g_2(x) = x^3 + x + 1$ are used. In Fig. 4b, initially flip-flops outputs are 001of Q3, $Q_2$, $Q_1$ and 001 of $\bar{Q}_3$, $\bar{Q}_2$, $\bar{Q}_1$ respectively. When the first clock

**Table 2** Truth table of Gold code generator (electronic version)

| CLK | Q (FF3) | Q (FF2) | Q (FF1) | $\bar{Q}$ (FF3) | $\bar{Q}$ (FF2) | $\bar{Q}$ (FF1) | Gold code | | |
|---|---|---|---|---|---|---|---|---|---|
| Initial | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 1st | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 2nd | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 |
| 3rd | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 |
| 4th | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 5th | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| 6th | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 7th | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |

pulse strikes the outputs are 011 and 010. In this manner the output bit patterns or the sequences obtained by simulation are shown in Table 2. After simulation we get 9 sets of Gold sequences.

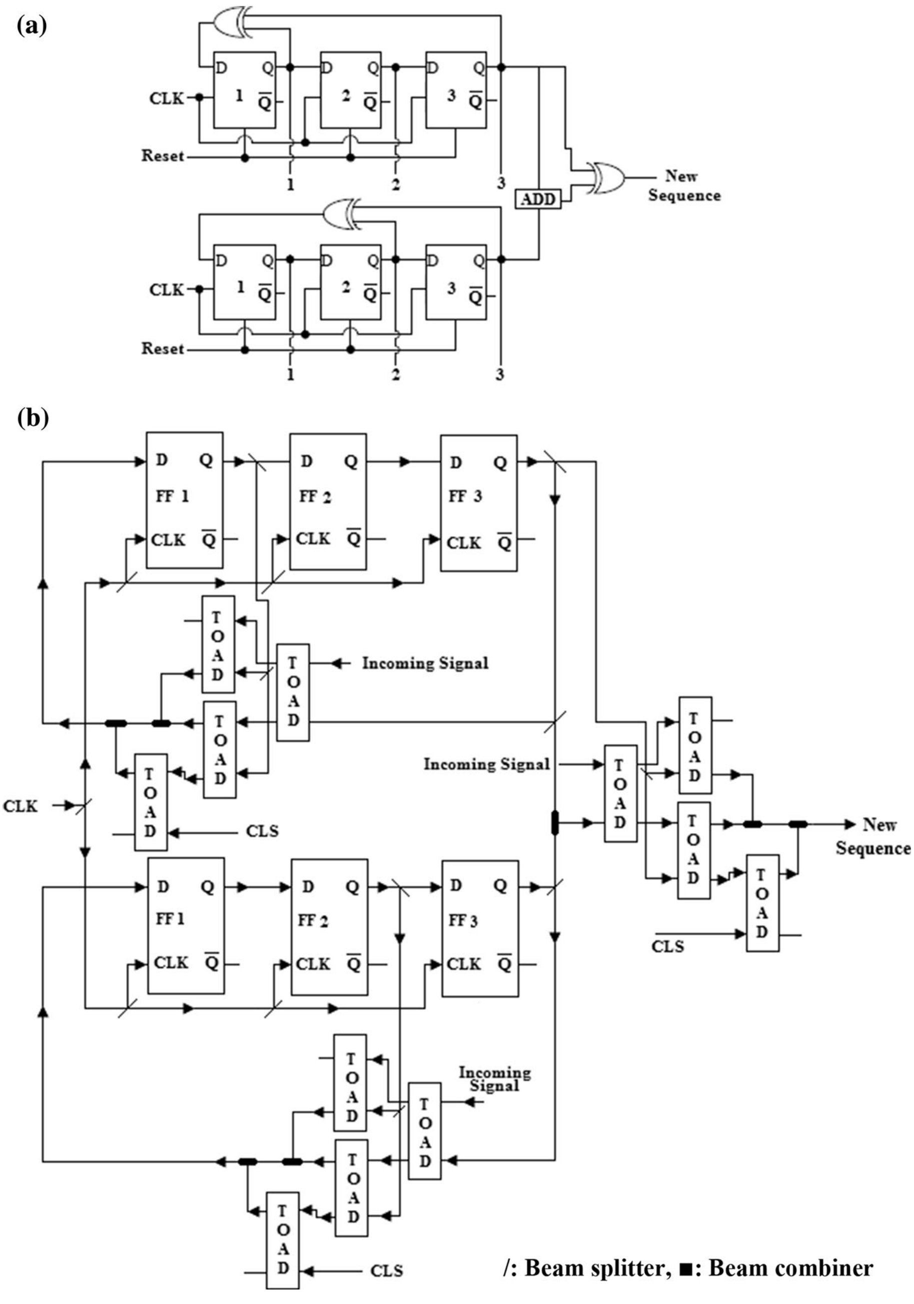


Fig. 5 Proposed MGS (code) generator, **a** electronic, **b** optical

**Table 3** Truth table of MGS (code) generator (electronic version)

| CLK | Q (FF1) | Q (FF2) | Q (FF3) | $\bar{Q}$ (FF1) | $\bar{Q}$ (FF2) | $\bar{Q}$ (FF3) | New sequence | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1st | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 2nd | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 |
| 3rd | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| 4th | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 |
| 5th | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 6th | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 7th | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |

## 3 Proposed: MGS (code) generator

Our proposed MGS (code) generator also uses the preferred pair of sequences as input. The block diagram of the circuit for polynomial of degree 3 is shown in Fig. 5. Instead of just using an XOR gate, first we add the two m-sequences which gives another m-sequence which is XORed with the one of the m-sequences. This modification allows more sequences to be obtained with reduced circuit design complexity as compared to the standard Gold sequence generator (Kolita and Sahu 2011). Using the same primitive polynomials as in the previous section ($g_1(x) = x^3 + x^2 + 1$ and $g_2(x) = x^3 + x + 1$), after simulation we get 12 sequences with $N = 2^3 - 1 = 7$—a 30 % improvement over the 9 sequences obtained with the Gold sequence generator.

In Fig. 5b, initially flip-flops outputs are 001 of Q3, $Q_2$, $Q_1$ and 001 of $\bar{Q}_3$, $\bar{Q}_2$, $\bar{Q}_1$ respectively. When the first clock pulse strikes the outputs are 010 and 110. In this fashion the output bit patterns or the sequences obtained by simulation are shown in Table 3. Figure 5b shows the proposed all-optical implementation of MGS (code) using TOAD. Here, all D-flip-flops as shown in this figure is implemented optically exactly in same way as shown in Fig. 2a, b. It is shown in Fig. 2a, b that each D flip-flop realization needs 3 TOADs and each X-OR realization needs 4 TOADs. Hence complete all optical MGS (code) realization needs in all ($6 \times 3 + 12$) i.e., 30 TOADs.

## 4 Results of simulation

Incoming and control pulse energy of every TOADs are Gaussian $\left[\frac{E_0}{\sigma\sqrt{\pi}}\exp\left\{-\left(\frac{t}{\sigma}\right)^2\right\}\right]$ in nature. The insertion loss (*I.L.*) of this circuit can be calculated by the following equation:

$$\text{I.L.}(dB) = 10log\left(\frac{P_{out}}{P_{in}}\right) \tag{5}$$

The equations of extinction ratio of the TOAD based switch are following (Shen and Wu 2008):

**Table 4** Parameters for simulation

| Parameters | Symbol | Value |
|---|---|---|
| Injection current of SOA | I | 120 mA |
| Unsaturated single-pass amplifier gain | $G_0$ | 17 dB |
| Line-width enhancement factor of SOA | $\alpha$ | 7.2 |
| Gain recovery time | $\tau_e$ | 270 ps |
| Saturation energy of the SOA | $E_{sat}$ | 1210 fJ |
| Eccentricity of the loop of TOAD | T | ~96 ps |
| Control pulse energy | $E_{cp}$ | ~200 fJ |
| Full width at half maximum of control pulse | $\sigma$ | 2.0 ps |
| Incoming pulse energy | $E_{in}$ | ~20 fJ |

**Table 5** Insertion loss of S–R flip-flop circuit for different inputs

| S–R flip-flop inputs | | S–R flip-flop outputs (in dB) | |
|---|---|---|---|
| S | R | $Q_{n+1}$ | $\bar{Q}_{n+1}$ |
| 0 | 1 | 11.6 | 06.4 |
| 0 | 0 | 11.6 | 06.4 |
| 1 | 1 | 11.6 | 11.6 |
| 1 | 0 | 06.4 | 11.6 |
| 0 | 0 | 06.4 | 11.6 |
| 1 | 1 | 11.6 | 11.6 |

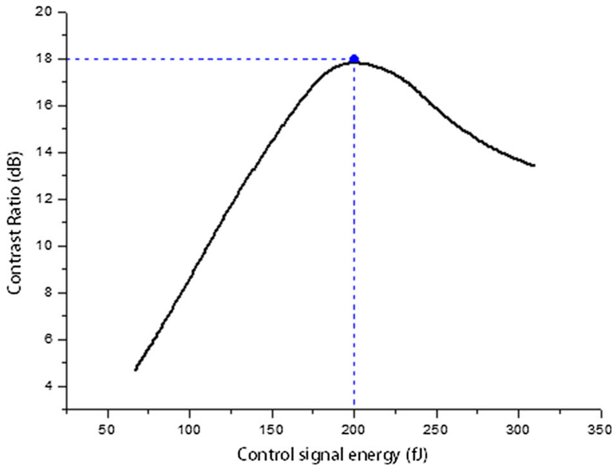


**Fig. 6** Variation of contrast ratio with control signal energy

$$\begin{aligned} Ex.R(dB)|^{OFF} &= 10\,\log\left(\frac{P_{out,2}}{P_{out,1}}\right)\bigg|_{Control=off} \\ Ex.R(dB)|^{ON} &= 10\,\log\left(\frac{P_{out,1}}{P_{out,2}}\right)\bigg|_{Control=on} \end{aligned} \tag{6}$$

With these formulae we obtain $Ex.R(dB)|^{OFF}$ = very high (because we get $P_{out,1}$ from theory is zero) and $Ex.R(dB)|^{ON} \approx 13$ dB. The minimum peak power when the pulse of the payload is high (1) say ($P^1_{Min}$) and the maximum when the pulse is low (0) say ($P^0_{Max}$) (Jung et al. 2008).

Then

$$C.R.(dB) = 10\,\log\left(\frac{P^1_{Min}}{P^0_{Max}}\right) \tag{7}$$

For all-optical computing and information processing this theoretical model and the results obtained numerically will be useful in future. The simulation is done by setting first the critical parameters as given in Table 4. Here, the presence of light is taken as ‘1’ state and absence of light is taken as ‘0’state. Simulation is done using Matlab-9. The insertion

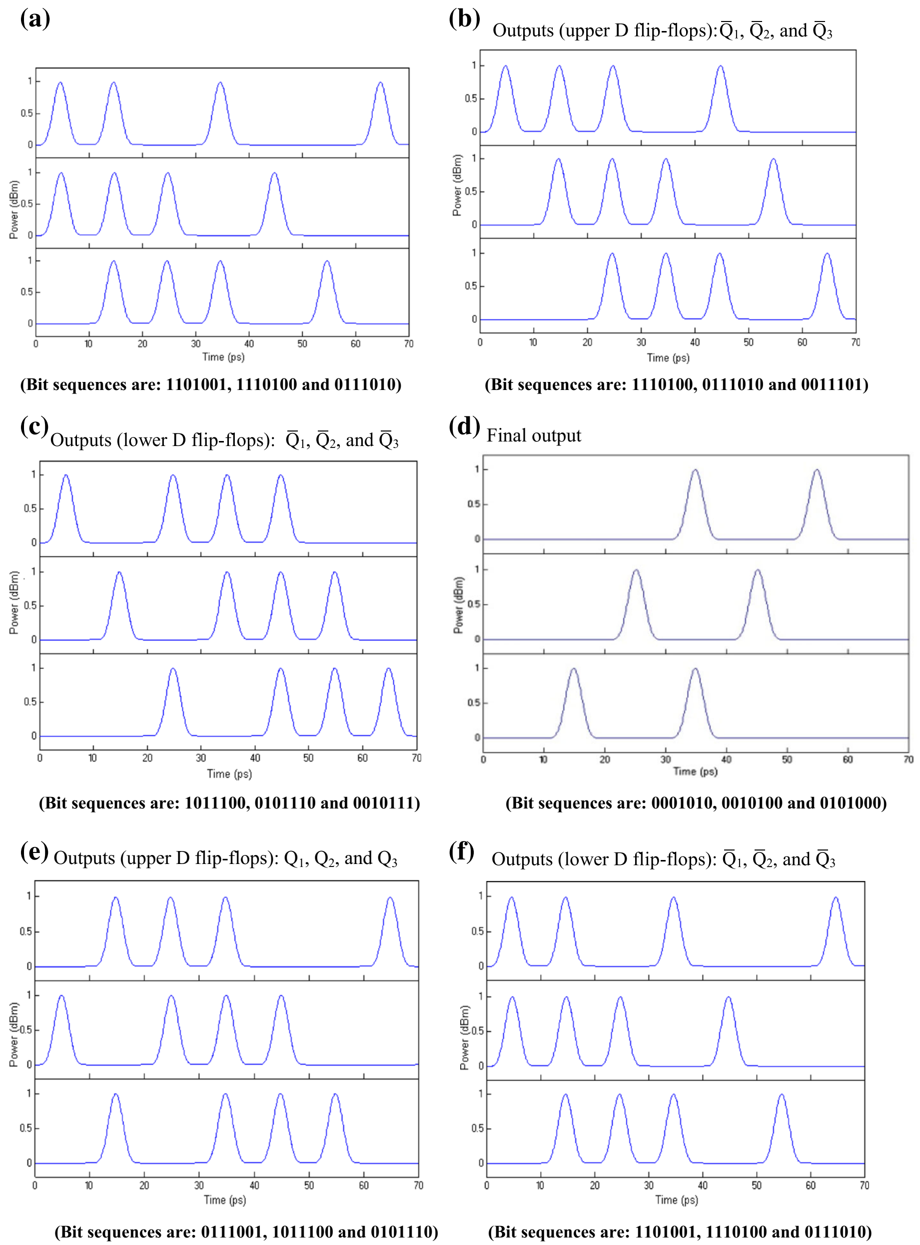


**Fig. 7** **a** Simulation results (of Fig. 3) of m-sequence. **b–d** Simulation results (of Fig. 4) of gold code. **e–h** Simulation results (of Fig. 5) MGS (code)

losses of S–R flip-flop circuit for different inputs and variation of contrast ratio with control signal energy are shown in Table 5 and Fig. 6 respectively.

The vertical axis in Fig. 7a–h indicates power in dBm, while horizontal axis represents time scale in ps.

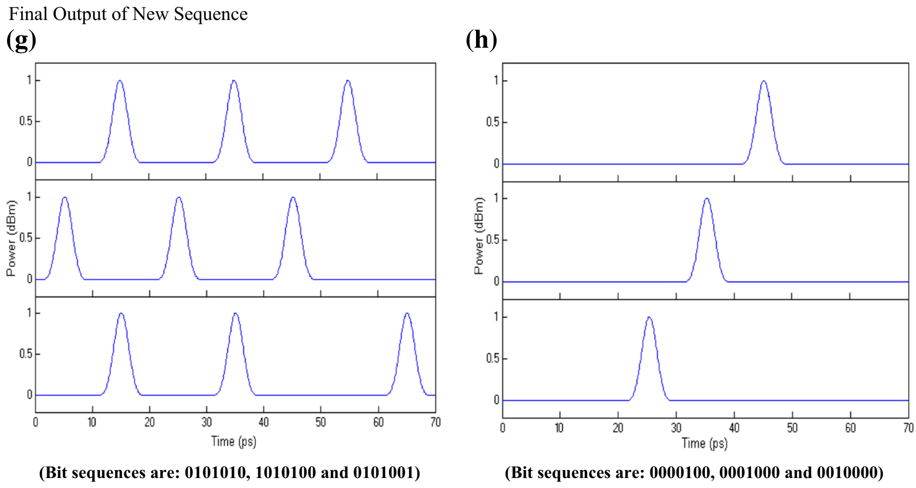


**Fig. 7** continued

The timing instant for the occurrence of bit pattern of new sequence or MGS (code) generator are at 5, 15, 25, 35, 45, 55, 65 ps. Upper twelve set waveforms of Fig. 7e–h, i.e., in Fig. 4. Figure 7e–h indicate the output bit sequences:

- 0111001, 1011100 and 0101110, are three outputs of $Q_1$, $Q_2$, and $Q_3$ (upper D flip-flops) and 1101001, 1110100 and 0111010 are three outputs of $\bar{Q}_1$, $\bar{Q}_2$, and $\bar{Q}_3$ (lower D flip-flops)
- (a) 0101010, 1010100, 0101001 and (b) 0000100, 0001000, 0010000 are six output of new sequence of Fig. 5b, respectively. Above those twelve outputs of simulation represent twelve sequences with $N = 2^3 - 1 = 7$.

## 5 Conclusion and future scopes

Spread Spectrum modulation techniques and data encryption schemes need longer and complex code sequences with better correlation properties to avoid jamming, experience low probability intercept and give good message hiding abilities. The construction of an all-optical new sequence or MGS (code) generator has been theoretically explained and presented. This proposed design is relied on discrete D flip-flops. These D flip-flops are serially connected for completely tapped to an XOR gate used for feedback. Here TOADs are the core building block for this scheme. The critical parameters of the simulation results indicate that the design can be used with a more than adequate contrast ratio and in a practically feasible way, which affirms that new sequence or MGS (code) generator can be created in the optical domain in its electronic counterpart, without complex adjustments in its standard constructional form. The intensity losses due to couplers in interconnecting stage may not produce much trouble for the required optical bits at the output as the whole system is digital one and the output depends only on the presence or absence of light. From the simulation results of proposed MGS, we have found that its autocorrelation function and cross-correlation function are same as that of the gold sequence generator. Here we generate 12 sets of sequences from the polynomial of degree 3. These sequence values are given in the previous section. As we increase the polynomial we generate more set of sequences. From the 12 set of sequences we may easily design a 3 channel CDMA system and also employ in underwater communication.

These design understanding is predicting regarding the issues of versatility, re-configurability and compactness. These circuits can be implemented and applied for various usages for which new sequence or MGS (code) is necessary in future. From the simulation and results of various sequences we have found that the new MGS has some advantages over the gold sequence. For multichannel system this sequence generator will be helpful since here we get large set of sequences.

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