Single Photon Source Driver Designed in ASIC

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Introduction

The QKD system has been proved to be unconditionally secure by the uncertainty principle and the no-cloning theorem in quantum mechanics. The ideal choice in the QKD system is the true single photon source. However, the suitable deterministic single photon source is still not available. We use the phase-random weak-coherent light emitted by the distributed feedback (DFB) laser as a source. To meet the needs of the QKD system for the source, the DFB laser should be precisely modulated. Therefore, a precise laser driver circuit is necessary. The 1550nm DFB laser needs a drive current pulse signal with the frequency up to 625MHz, the pulse width from 400ps to 800ps, and the amplitude from 20mA to 100mA. Because of the fast speed and the high current of the drive signal, most of the single photon source drivers we use consist of a lot of discrete components. For the better performance, the design of the circuit board must be very compact. To make the driver more integrated, we designed an ASIC chip named LSD2018, a laser source driver chip used to drive the 1550nm DFB laser in random pulse mode.
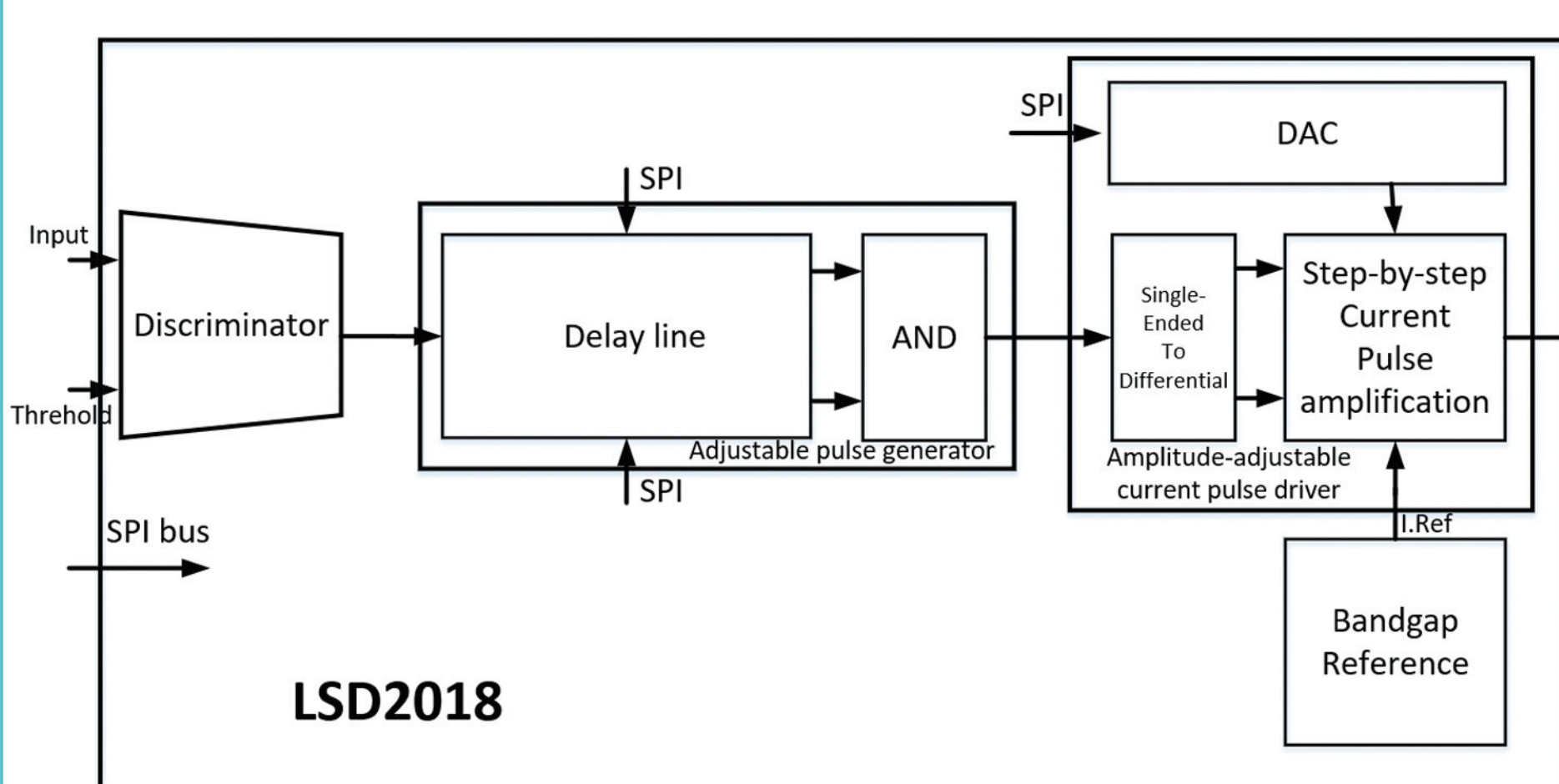
Fig.1. The structure of the LSD2018

Design Scheme

The structure of the LSD2018 is shown on Fig.1. The LSD2018 consists of a discriminator, an adjustable pulse generator, a bandgap reference, an SPI bus, and an amplitude-adjustable current pulse driver.

A. Adjustable Pulse Generator

The adjustable pulse generator consists of a delay line and an AND gate. The generator receives the signals from the discriminator and generates two time-delay signals by the delay line. The two time-delay signals are different in delay time and phase. So, when the two signals are added by the AND gate, we can get a narrow pulse signal. The pulse width of the narrow pulse signal is determined by the relative delay of the two time-delay signals. The delay of the two time-delay signals is configured by the SPI bus.

B. Amplitude-adjustable Current Pulse Driver

The amplitude-adjustable current pulse driver consists of a single-ended to differential module, a step-by-step current pulse amplification module, and a 4-bit DAC. The single-ended to differential module receives the output signal from the adjustable pulse generator and converts it from a single-ended signal to a differential signal. The step-by-step current pulse amplification module converts the differential signal into a current pulse signal and amplifies the current amplitude step by step. Finally, it generates a signal with high current amplitude up to 120mA to drive the laser. The amplitude of the output current can be configured by the DAC. The DAC is configured by the SPI bus.

The chip is designed in a 130nm CMOS process. The die size is 2400nm × 1200nm and consists of 4 different drivers. They are different from each other in parameters and integration. So that, we can test more easily and comprehensively. The layout of the LSD2018 is shown in the center of the poster.

Simulation

The LSD2018 tape-outed on May 15, 2018. The schedule delivery date is August 2018. In the paper, we provide simulation results only. We simulated across different process corners (tt, ss, ff) and at different temperatures (0℃, 27℃, 85℃). In the simulation on layout in different conditions, the chip is fully functional. The structure of simulation is shown in Fig. 2. Considering the influences of the parasitic parameters, some resistances, capacitances and inductances are connected in the rail of power and the line of input and output. We place a pull-up resistor at the output as the 1550nm DFB laser.

The Fig. 3 is the "eye diagram" of the simulation which the output current frequency is 625MHz, the pulse width is 400ps, and the amplitude is 60mA at the process corner tt and 27℃. The off current is less than 0.6mA. The time jitter is about 20ps on the rising edge, and about 30ps on the falling edge. The range of the amplitude change is about 2mA at 60mA. The design indicators and the simulation results are shown in Table 1. The LSD2018 can generate a current pulse signal of which the frequency is up to 625MHz, the amplitude is from 20mA to 120mA and the pulse width is from 400ps to 4ns. It can satisfy the requirements of the 1550nm DFB laser.
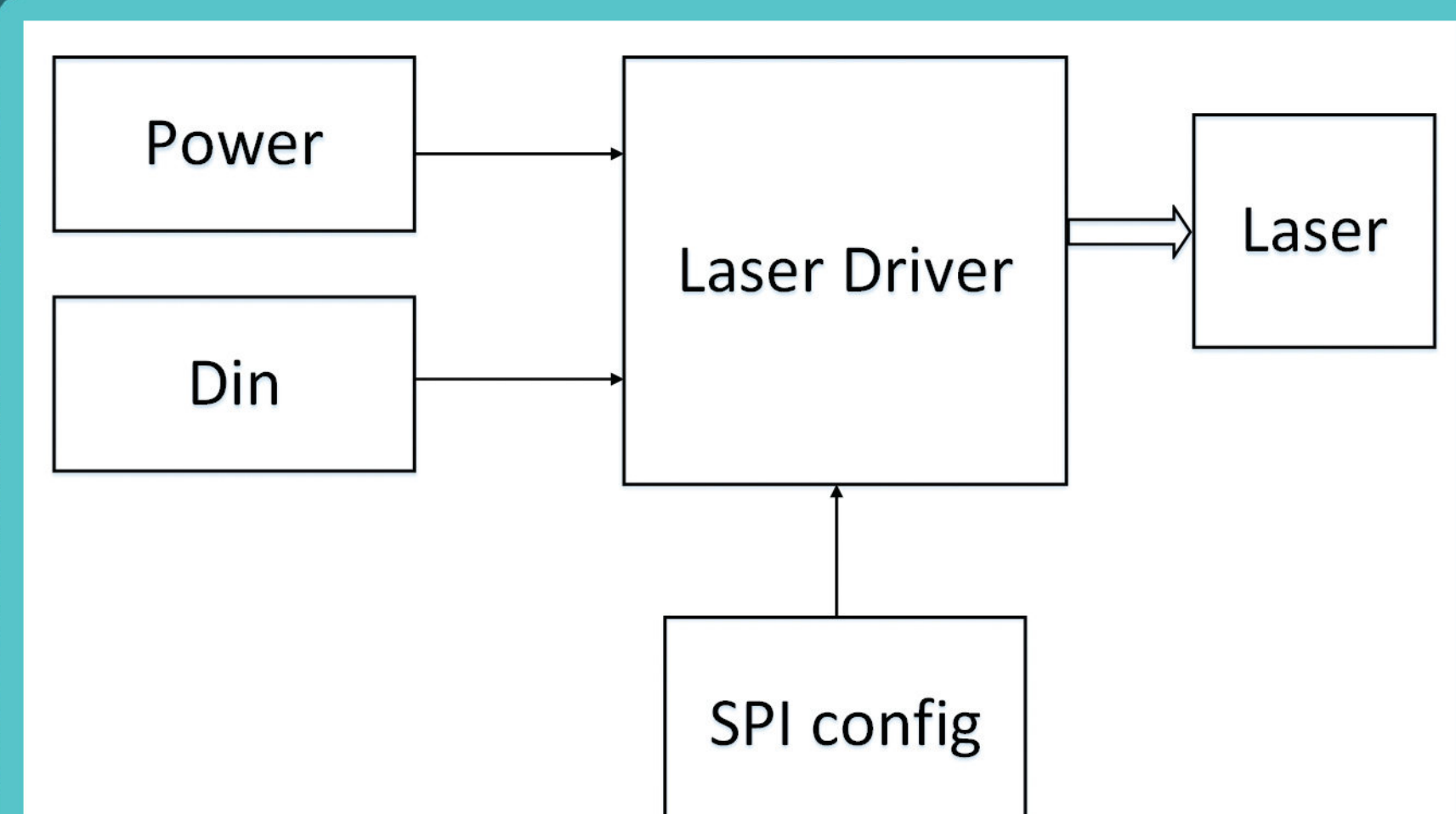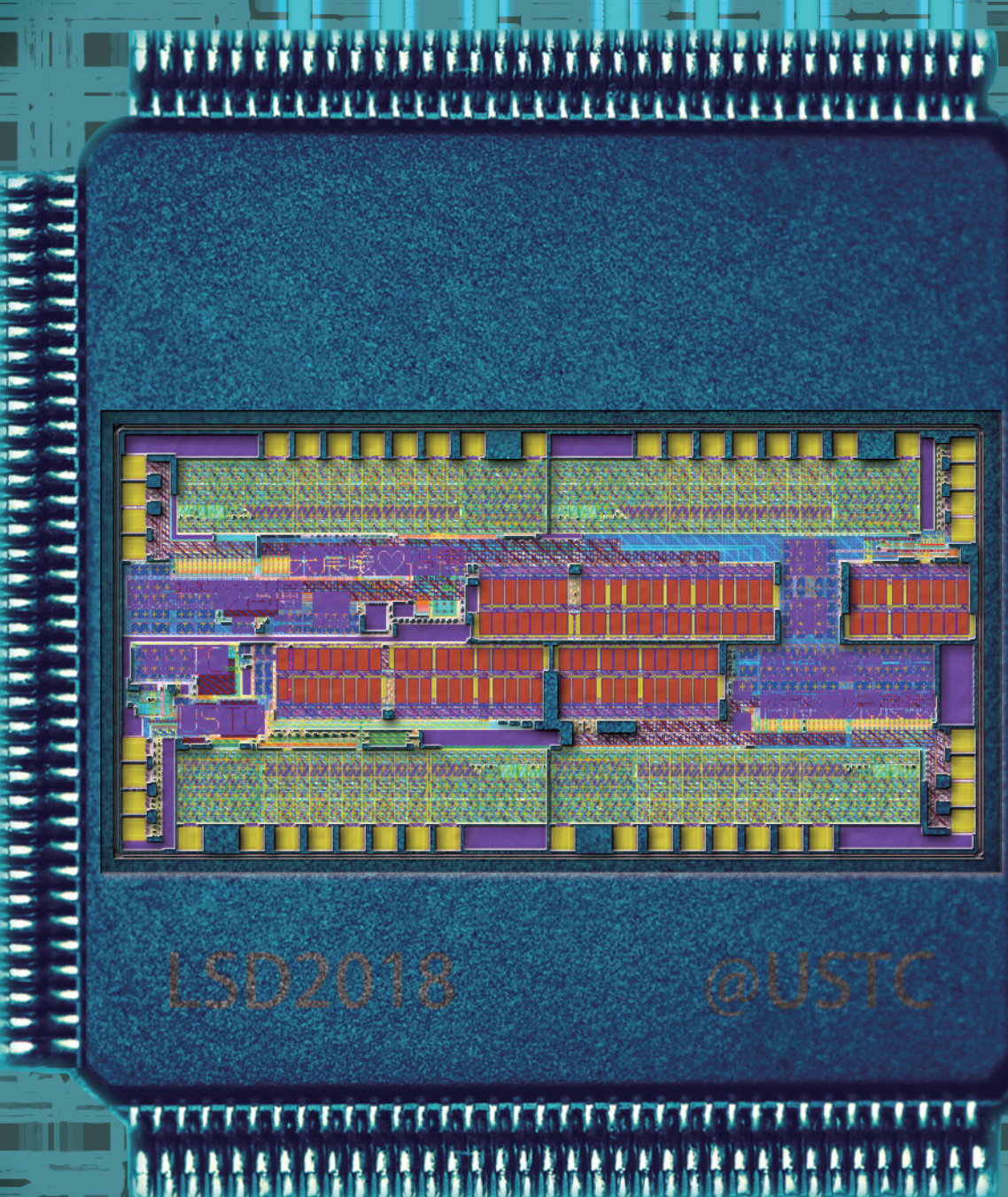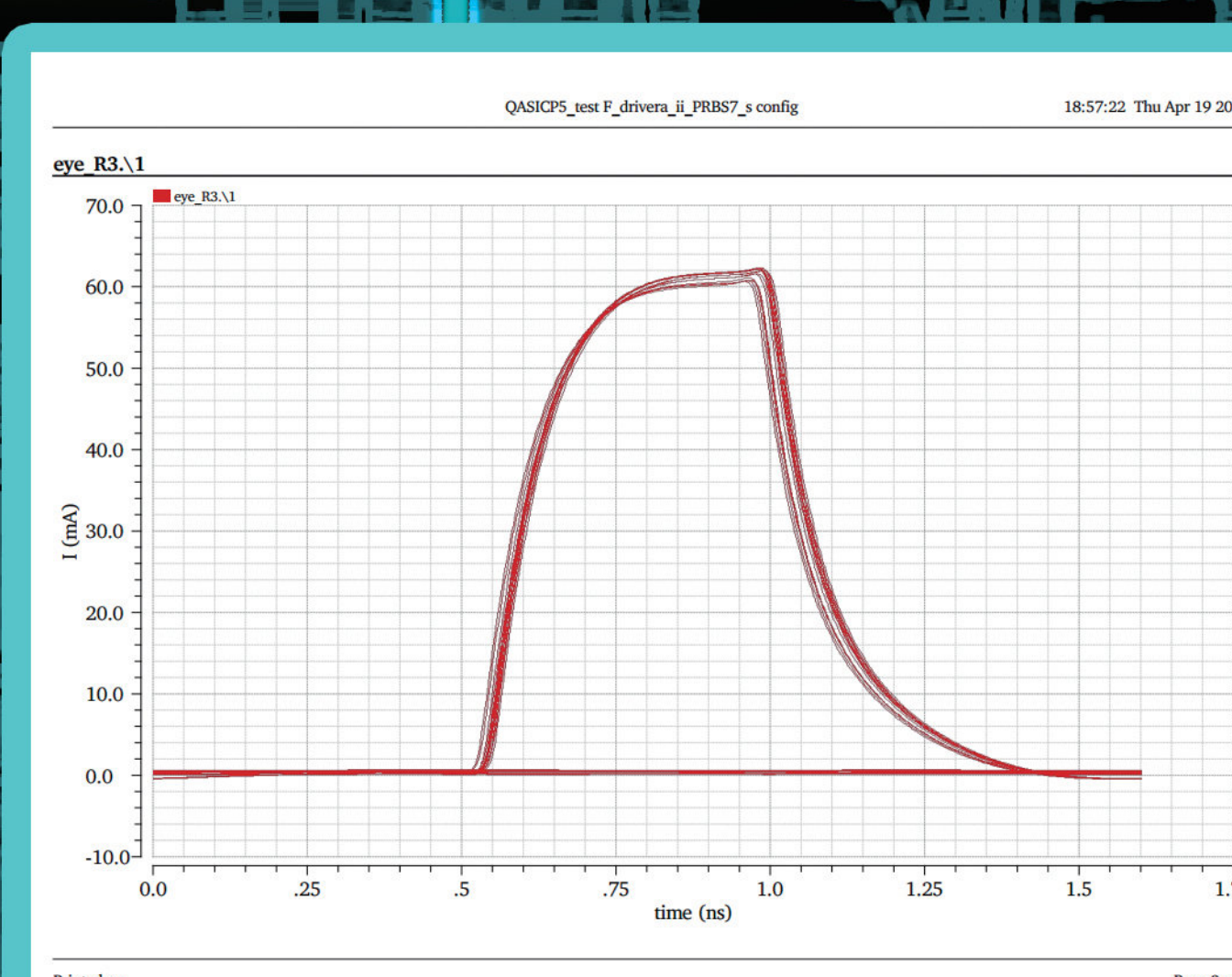
Fig. 2. The layout of simulation

Fig. 3. the "eye diagram" of the simulation (Because the output current signal is a pulse signal which only consists of long 0 and short 1, the "eye diagram" looks incomplete.)

TABLE I
THE DESIGN INDICATORS AND THE SIMULATION RESULTS OF THE LSD2018

	Project indicators	simulation results
Maximum output frequency	625MHz	625MHz
Minimum output pulse width	400ps	400ps
Output current amplitude	20mA-100mA	20mA-120mA

Conclusion

In the primary simulation, the LSD2018 is fully functional. It can generate a drive current pulse signal with the high current from 20mA to 120mA, the narrow pulse width from 400ps to 4ns, and the fast speed up to 625MHz. The drive signal can ideally drive the 1550nm DFB laser.

By integrating laser driver electronic module into one ASIC chip, the LSD2018 greatly reduces the volume of the single photon source driver. It is the beginning of the miniaturization of the QKD system. The full performance tests will be done when the LSD2018 is delivered.