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Dual-wavelength DFB Laser Based on Four Phase-shifts Sections and Equivalent Chirp Technology for Millimeter-wave Generation

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A monolithic dual-wavelength DFB laser based on four phase-shift (4PS) sampling sections and equivalent chirp technology is proposed and experimentally demonstrated. Dual-wavelength lasing is achieved by introducing two π phase shifts at positions 1/3 and 2/3 along the length of the DFB laser cavity [1]. Compared to conventional sampled Bragg gratings, the 4PS sampling structure has a higher grating coupling coefficient, κ, for the +1st channel, with κ equal to 0.9 times that of a uniform seed grating [2,3]. Meanwhile, the equivalent chirp technology is applied by linearly modulating the sampling periods along the DFB cavity, thus ensuring the peaks in the photon distributions of the two lasing modes at separate locations along the cavity. Consequently, mode competition between the two modes can be largely suppressed [1]. An electro-absorption modulator (EAM) section is also integrated with the DFB laser to enhance the phase locking between the two lasing modes. Furthermore, the device is based on sidewall grating, which needs only one metalorganic vapor-phase epitaxy (MOVPE) step and one III-V material dry etching step, simplifying the device fabrication process.

As shown in Fig. 1(a), the grating in each sampling period is evenly divided into four sections, with each adjacent grating section subjected to a $\pi/2$ phase shift. Both sidewalls have the same uniform seed grating with a period of 257 nm, the sampled gratings are modulated along the DFB laser cavity with a linear chirp rate of 90 nm/mm, and the average sampling period is 4.711 µm. The 2.5-µm-wide ridge waveguide (W=2.5 µm) and grating pattern with 0.6 µm recess depth are defined by electron-beam lithography (EBL) with a resolution of 0.5 nm using hydrogen silsesquioxane (HSQ) as both the resist and dry etching mask. Fig. 1(b) shows the sampling period distribution along the cavity (z-direction), the difference in period between the first sampling period P_1 and the final sampling period P_n being 63 nm. The device comprises an EAM section (L_{EAM}=30 µm) and a DFB laser section (L_{DFB}=700 µm), separated by an electrical isolation groove (20-µm-long) (see Fig. 1(c)).

After fabrication, the devices were mounted epilayer-up on a copper heat sink with a Peltier cooler. The heat sink temperature was set at 20 °C and the devices were tested under CW conditions, with all results measured from the DFB side. As shown in Fig. 2(a), two lasing modes (λ_1=1555.321 nm, λ_2=1555.819 nm) can be clearly observed when a 60 mA injection current and –0.3 V reverse voltage are applied to the DFB and EAM respectively. The two optical signals were incident on a photodetector (PD) connected to a mixer and an electrical spectrum analyzer (ESA) and the radio frequency (RF) spectrum of the beating tone was measured. In Fig. 2(b), a 61.2 GHz RF signal is observed, which is consistent with the frequency difference between λ_1 and λ_2 (Fig. 2(a)). The frequency difference between λ_1 and λ_2 can be designed by changing the values of the two phase shifts and the chirp rate [1].

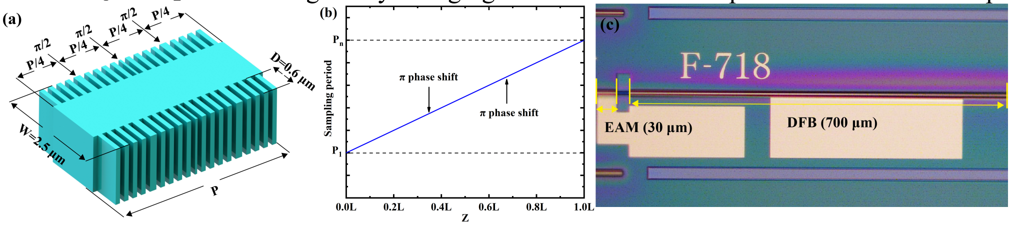

Fig. 1. (a) Schematic of the 4PS structure (one sampling period P), (b) sampling period distribution along the DFB laser cavity, (c) microscope image of the device.

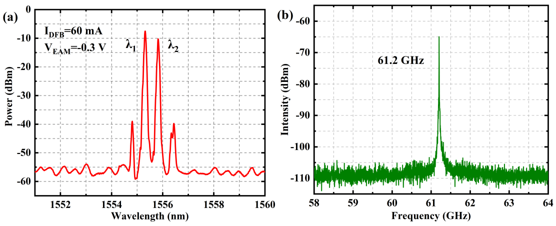

Fig. 2. (a) Measured optical spectrum, and (b) RF spectrum.

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