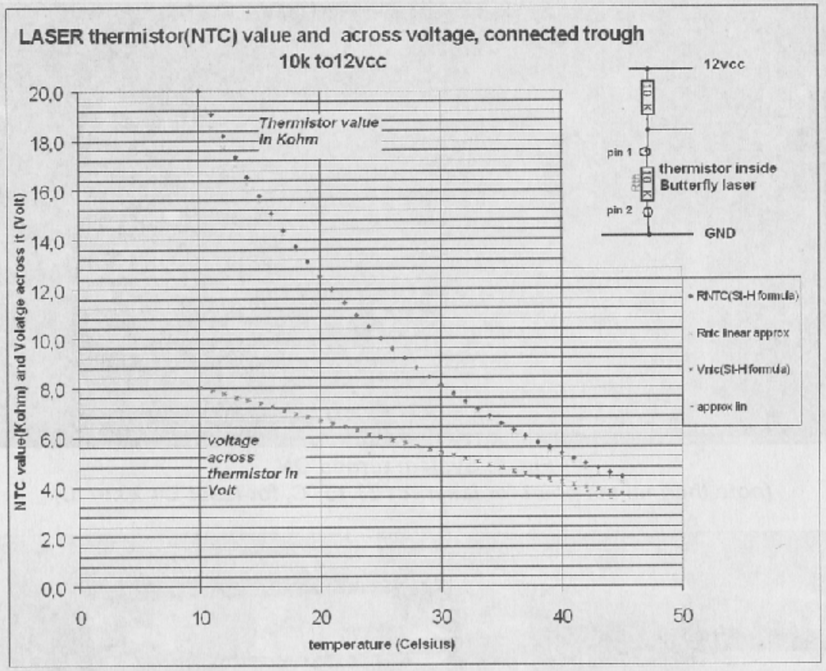

note:St-H= Steinhardt-Hart formula for thermistor

Fig. 8

Output signals could be useful to test receiving equipment at 5-10-24…GHz with one single piece of equipment. The cost of this system depends on the DWDM lasers, but refurbished or obsolete parts can be found on eBay at very low prices (10-100 $).

Future applications

This system could lead to a microwave sweep source covering several decades, a cost effective single unit suitable for testing filters, preamps and other equipment covering 5-10-24-47 GHz and above. We are working to improve the detector bandwidth, which is related to the photodiode type.

Acknowledgement

Thanks to Luis Cupido, CT1DMK, for essential repairs to the HP8563E microwave analyzer.
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P.I.D. controller for Thermoelctric Cooler (TEC) placed inside Butterfly Laser

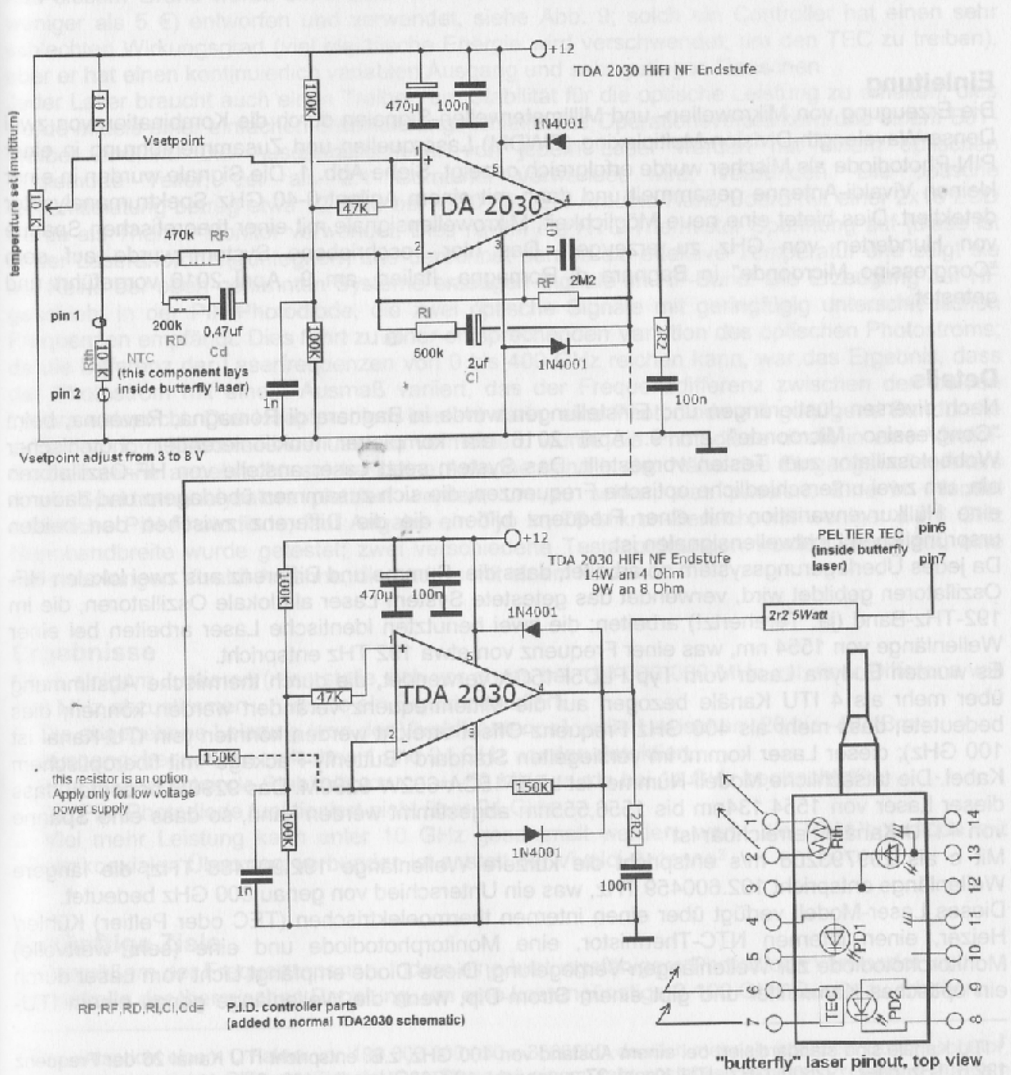

Fig. 9: Circuit diagram of the Peltier controller

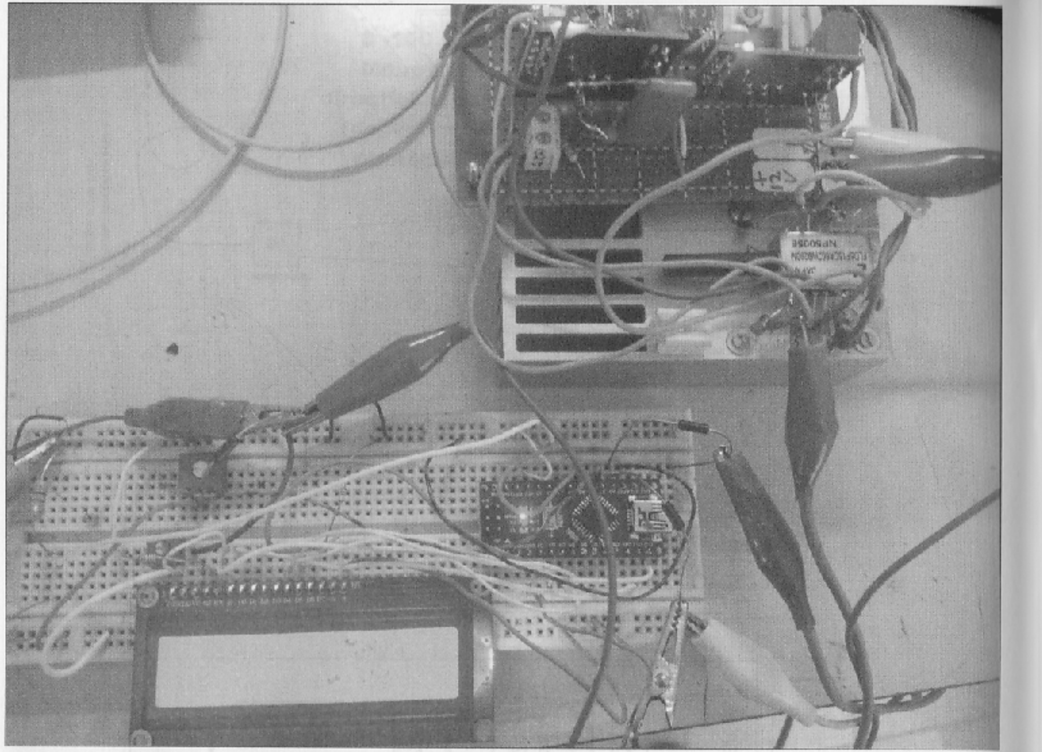

Fig. 3: Preliminary debugging the Arduino board for the TEC controller (bottom left: LCD display showing thermistor voltage for laser a and laser b and the related temperatures; middle: Arduino nano board; upper: FLD5F15 laser and thermal controller)

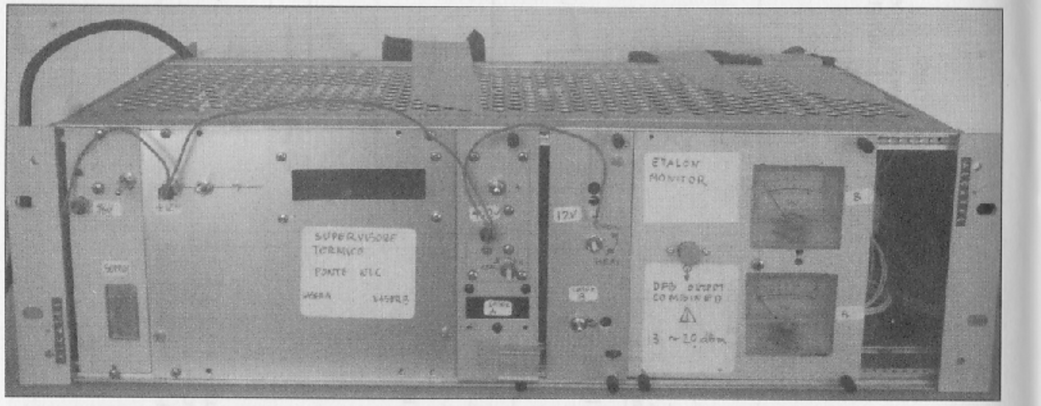

Fig. 4: Completed system (from left to right: stabilized power supply, Arduino controller, laser unit A, laser unit B, double wavelength locking monitor.
The green cap is the optical output, singlemode fibre FC/APC connector)

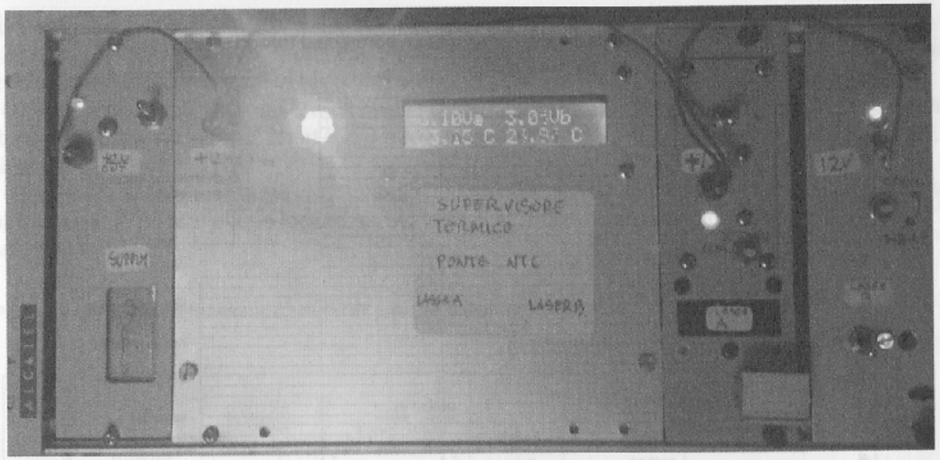

Fig. 5: System turned ON,
(note thermal set point for laser A= 23.15 °C, for laser B= 23.97°C)

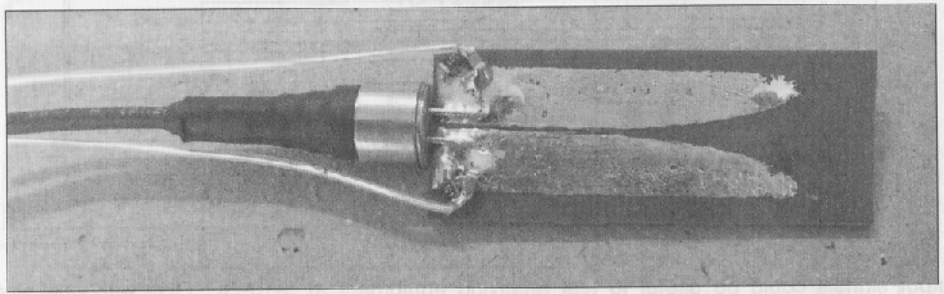

Fig. 6: A commercially available photodiode mounted on a Vivaldi horn (left: fibre pigtail of the photodiode, white wires carry bias to the diode to maximize conversion)

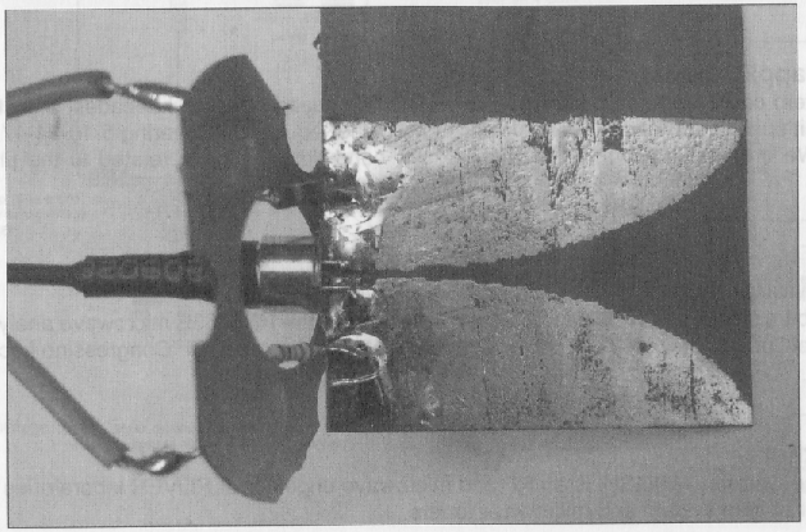

Fig. 7: Another photodiode, mounted on a stepped Vivaldi horn

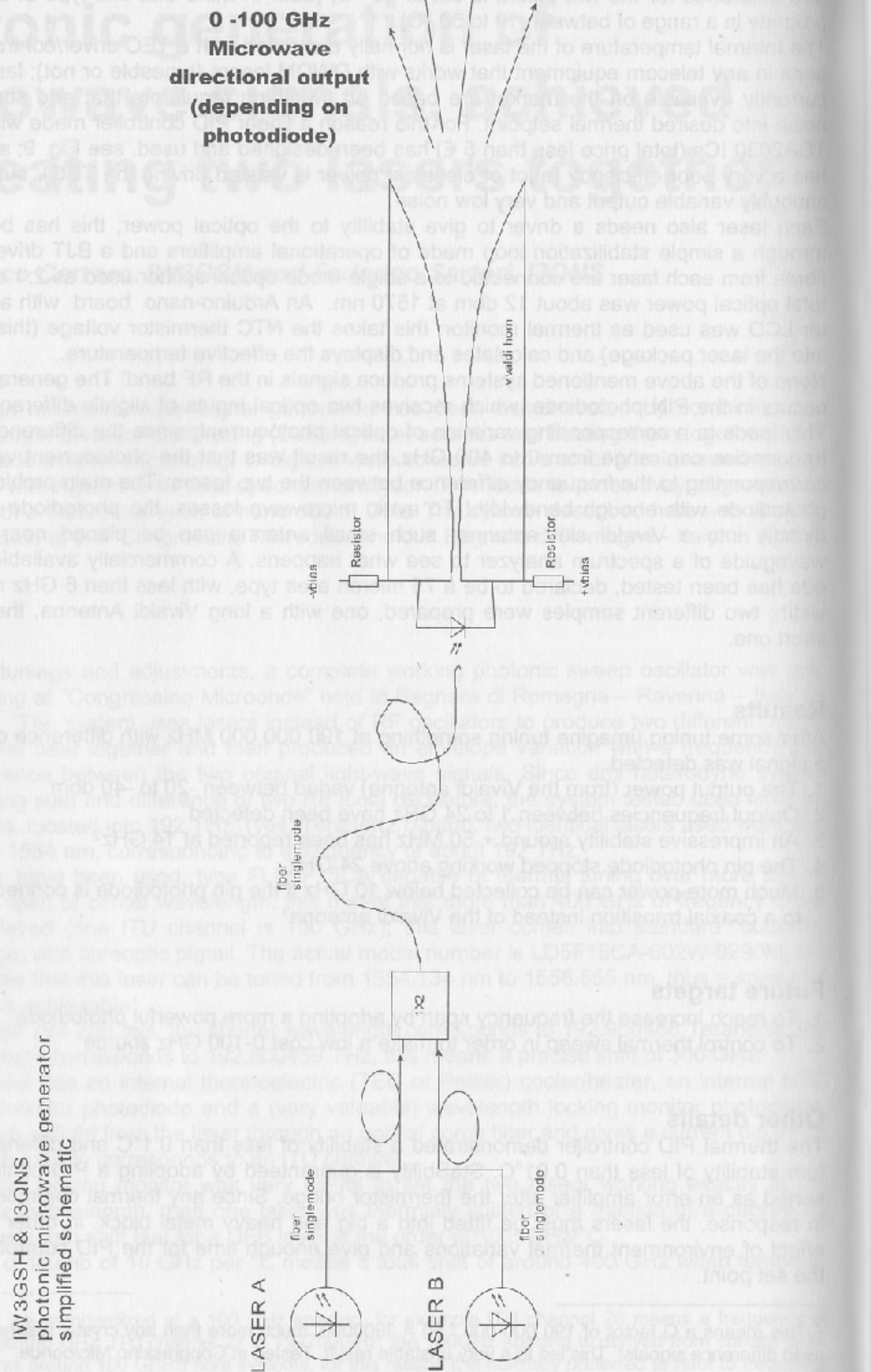

Fig. 1: Principle of operation

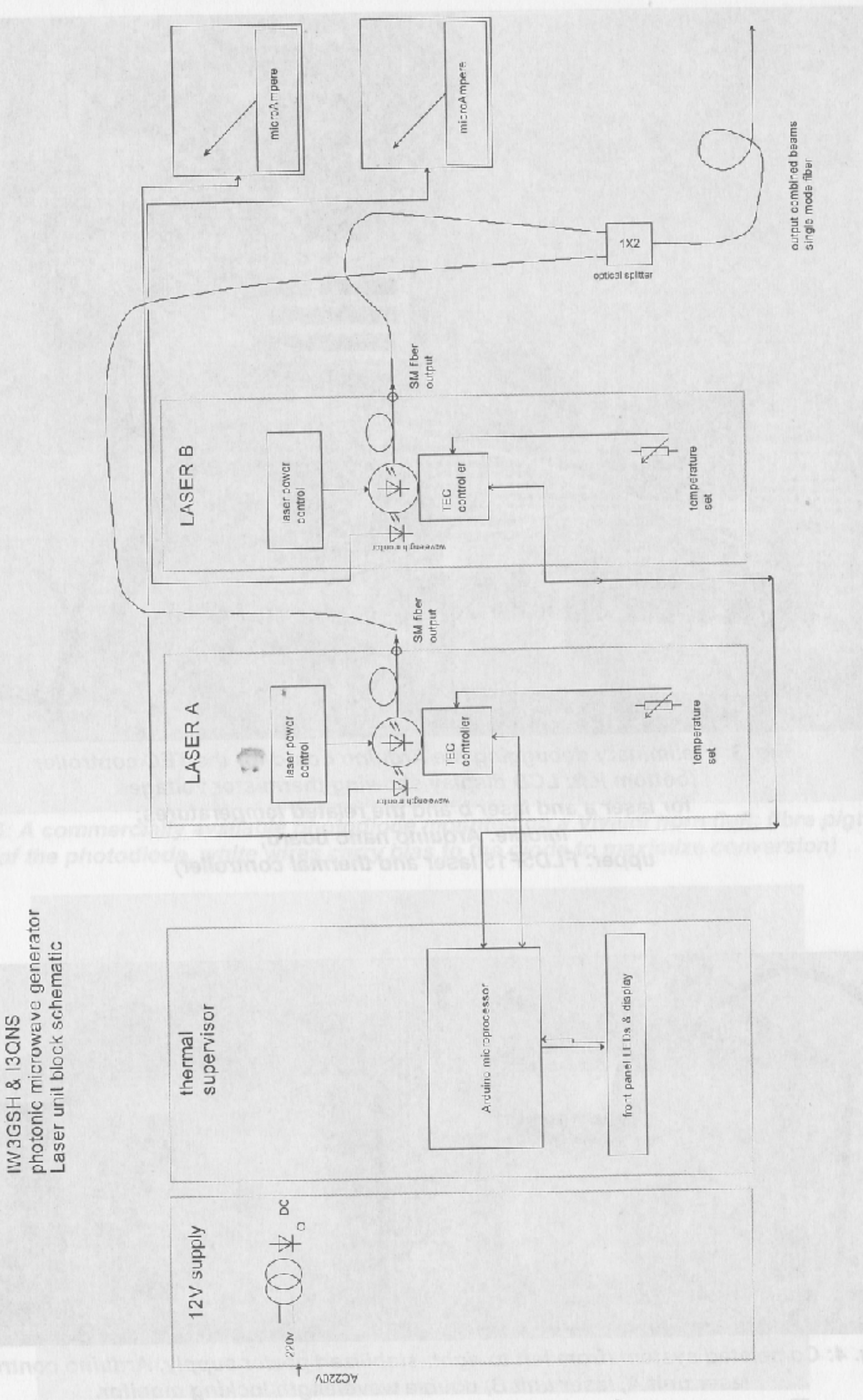

Fig. 2: Block diagram of the laser unit

Photonic generation of microwave signals, achieved by beating two lasers together

by Francesco Carraro, IW3GSH and Federico Sartori, I3QNS

Abstract

Microwave and millimetre wave signal generation has been demonstrated by combining two Dense-Wavelength-Division-Multiplexing (DWDM) laser sources and beating them together using a PIN photodiode as a mixer. See fig. 1. Signals were collected into a small Vivaldi launcher, and then detected with Agilent 0-40 GHz spectrum analyzer. This leads to a new way of generating uW signals with a theoretical span of hundreds of GHz. The system described here was demonstrated and tested at the "Congressino Microonde" held in Bagnara di Romagna - Italy on April 9, 2016.

Details

After several tunings and adjustments, a complete working photonic sweep oscillator was prepared for testing at "Congressino Microonde" held in Bagnara di Romagna – Ravenna – Italy on 9th April 2016. The system uses lasers instead of RF oscillators to produce two different optical frequencies that beat together and then produced an envelope variation with a frequency that was the difference between the two original light-wave signals. Since any heterodyne system works producing sum and difference of two RF local oscillators, the system tested used laser as local oscillators, located into 192 THz (yes, Terahertz !) band; two identical lasers used work at a wavelength of 1554 nm, corresponding to a frequency of about 192 THz.

Eudyna lasers have been used, type FLD5F15CA capable of thermal tuning over more than 4 ITU channels span of center wavelength; this meant that more than 400 GHz of freqency offset could be achieved (one ITU channel is 100 GHz); this laser comes into standard "butterfly" sealed package, with fibreoptic pigtail. The actual model number is LD5F15CA-602W-9290M, the 9290M indicates that this laser can be tuned from 1554.134 nm to 1556.555 nm, thus a span of 4 ITU channels is achievable[1].

Taking c as 299 793 208 m/s, the shorter wavelength corresponds to 192.900488 Terahertz; the longer wavelength corresponds to 192.600459 THz, this means a precise shift of 300 GHz.

This laser model has an internal thermoelectric (TEC or Peltier) cooler/heater, an internal NTC thermistor, a monitor photodiode and a (very valuable) wavelength locking monitor photodiode; this diode receives light from the laser through an optical comb filter and gives a current dip when the wavelength exactly corresponds to an ITU channel.

The wavelength locking monitor was very useful to set the two lasers working exactly at the same frequency/wavelength, then one laser was thermally shifted of a fraction of a degree, to achieve a wavelength shift that for a DFB laser is the order of 10.3 GHz/°C.

A simple rule of thumb of 10 GHz per °C means a total shift of around 400 GHz when temperature difference for the two lasers is set to 40 °C, (bear in mind that this type of laser operates properly in a range of between 10 to 50 °C).

The Internal temperature of the laser is normally controlled with a TEC driver/controller, this happens in any telecom equipment that works with DWDM lasers (tuneable or not); laser controllers currently available on the market are based on switching regulators that add some regulation noise into desired thermal setpoint. For this reason a linear PID controller made with a couple of TDA2030 ICs (total price less than 5 €) has been designed and used, see Fig. 9; such controller has a very poor efficiency (a lot of electrical power is wasted driving the TEC), but it has a continuously variable output and very low noise.

Each laser also needs a driver to give stability to the optical power; this has been achieved through a simple stabilization loop made of operational amplifiers and a BJT driver. The output fibres from each laser are connected to a single-mode optical splitter used as 2:1 combiner. The total optical power was about 12 dbm at 1570 nm. An Arduino-nano board with a 2x16 character LCD was used as thermal monitor; this takes the NTC thermistor voltage (this is integrated into the laser package) and calculates and displays the effective temperature.

None of the above mentioned systems produce signals in the RF band! The generation of the RF occurs in the PIN photodiode, which receives two optical inputs of slightly different frequencies. This leads to a corresponding variation of optical photocurrent; since the difference of the laser frequencies can range from 0 to 400 GHz, the result was that the photocurrent varies at a rate corresponding to the frequency difference between the two lasers. The main problem is to find a photodiode with enough bandwidth! To avoid microwave losses, the photodiode was mounted directly into a Vivaldi slot antenna; such small antenna can be placed near to the input waveguide of a spectrum analyzer to see what happens. A commercially available pin photodiode has been tested, declared to be a 75 micron area type, with less than 6 GHz nominal bandwidth; two different samples were prepared, one with a long Vivaldi Antenna, the other with a short one.

Results

After some tuning (imagine tuning something at 190 000 000 MHz with difference of 100 MHz…) a signal was detected.

1. The output power (from the Vivaldi antenna) varied between -20 to -40 dbm
2. Output frequencies between 1 to 24 GHz have been detected
3. An impressive stability around +-50 MHz has been reported at 14 GHz[2]
4. The pin photodiode stopped working above 24 GHz
5. Much more power can be collected below 10 GHz if the pin photodiode is connected to a coaxial transition instead of the Vivaldi antenna[3]

Future targets

1. To reach increase the frequency span by adopting a more powerful photodiode
2. To control thermal sweep in order to make a low cost 0-100 GHz source

Other details

The thermal PID controller demonstrated a stability of less than 0.1°C and differential temperature stability of less than 0.01°C. StaSbility is guaranteed by adopting a PID controller loop, inserted as an error amplifier after the thermistor bridge. Since any thermal controller is very slow in response, the lasers must be fitted into a big and heavy metal block, in order to reduce the effect of environment thermal variations and give enough time for the PID controller to readjust the set point.

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[1] ITU channels are standardized at a 100 GHz spacing, for example ITU channel 26 means a frequency of 192.6 THz or 192600 GHz, ITU channel 27 is 192700GHz; the 100GHz spacing is derived from current technology, that works around 100 GBPS fibre systems, for this reason it is normally preferred to refer to frequency instead of wavelength.

[2] This means a Q factor of 190 000 000 / 50 = 3800000, much more than any crystal resonator, anyway we used difference signals! This led to a very unstable result. Tested at Congressino Microonde.

[3] not tested at "Congressino Microonde", but at IW3GSH's laboratory