

# Signal Generating for the mm-Wave Bands

Michael Kuhne DB6NT / Gert Weinhold DG8EB

Most millimeter-wave mixers used in amateur radio are subharmonic mixers, which are also used for transmitting (TX). The generated transmitting power is usually about 0.2 mW SSB or even less. If harmonic mixers are used instead, the SSB power is still far smaller (about 10 - 50  $\mu$ W). Since access to power amplifier chips and their processing is very difficult and expensive, the path of frequency multiplication is well suited to achieve a transmit power in the milliwatt range. This procedure requires as much power as possible to control the multipliers.

## 122 – 134 GHz signal generation:

A CW transmitter using a diode frequency doubler for 122 and 134 GHz requires 61 and 67 GHz as the control frequency. In my search for suitable chips for these frequencies I found the sixfold **gXSB0019A** and the power amplifier **gAPZ0039A** by the company gotMIC from Gothenburg (Sweden).

This combination promises an output power of 400 mW ( $P_{sat}$ ) at a drive of 15 mW (10 or 11.2 GHz) to control a power frequency doubler.

The circuit board is made of RT5870 0.12mm and soldered to a previously machined brass plate. The slots for the chips and capacitors are milled out after soldering. The power supply is mounted in the cover. This consists of a step-down converter (OKR-T / 3 series) and a minus voltage generation with the LT1054 IC.

## Adjustment:

First, the DC voltages are adjusted to the values specified in the circuit diagram with the setting controls. Then we put the control frequency with about 15 mW on the input and measured the output power. Now the fine adjustment can be done. This is done by optimizing the gate voltages (operating points), as well as by setting the short-circuit slider at the waveguide transition.

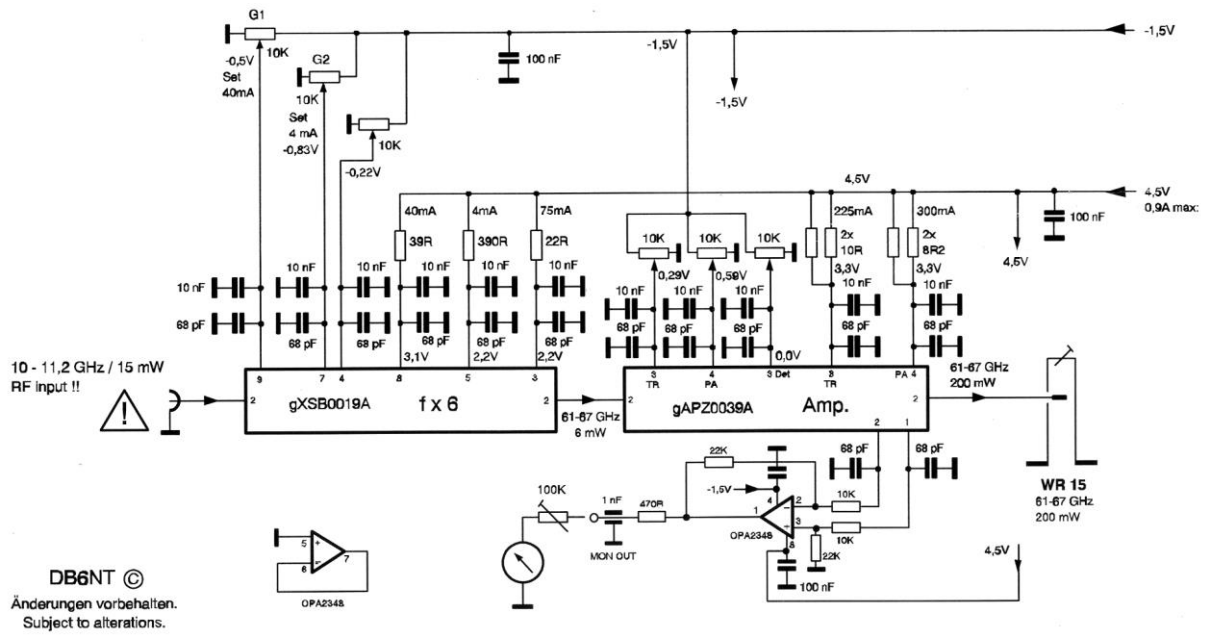
The transition is a little bit critical and is only optimal for one LO frequency. The maximum output was 240 mW at 61.125 GHz. Unfortunately, the "datasheet power" of 400 mW was not reached. With an adjustment that also includes the frequency 67.464 MHz (134 GHz band), only about 160 mW are expected.

The OP amplifier circuit for detecting the output power can be dimensioned even more optimal. The company **GotMIC** - which is the chip manufacturer - was unfortunately not able to provide a precise circuit proposal.

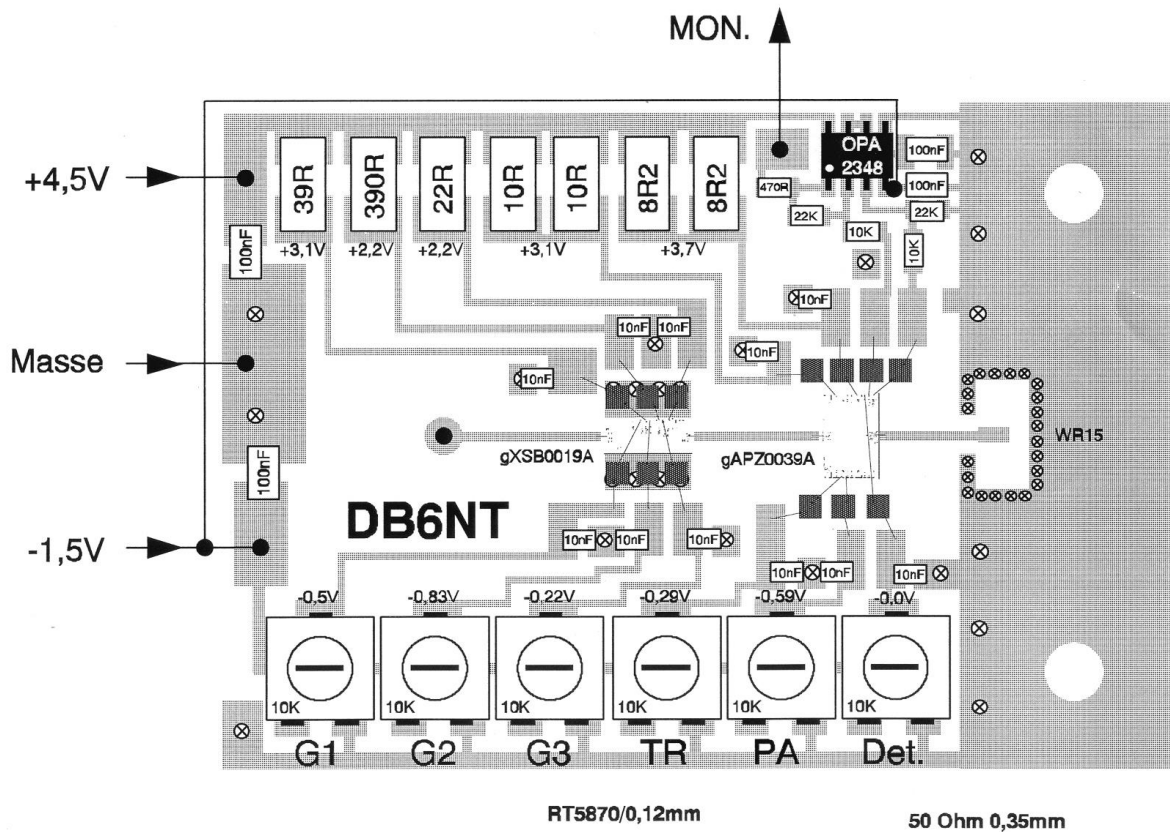
I think 200 mW is a considerable LO performance for driving a doubler. Currently I am using a doubler from **Virginia Diodes**. Gert, DG8EB, is currently testing a self-made variant of a doubler. We will report about it.

To control this module we use the oscillator module MKU LO 8-13 PLL.

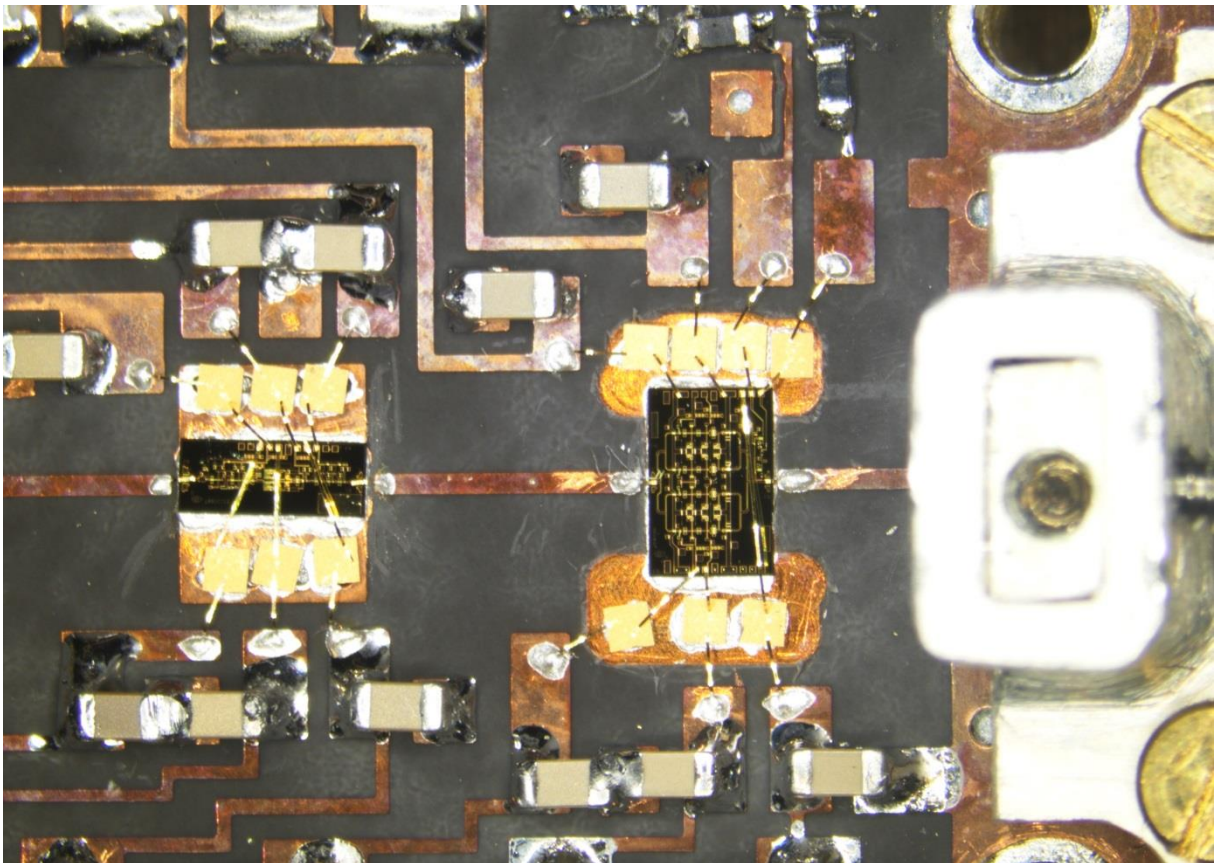
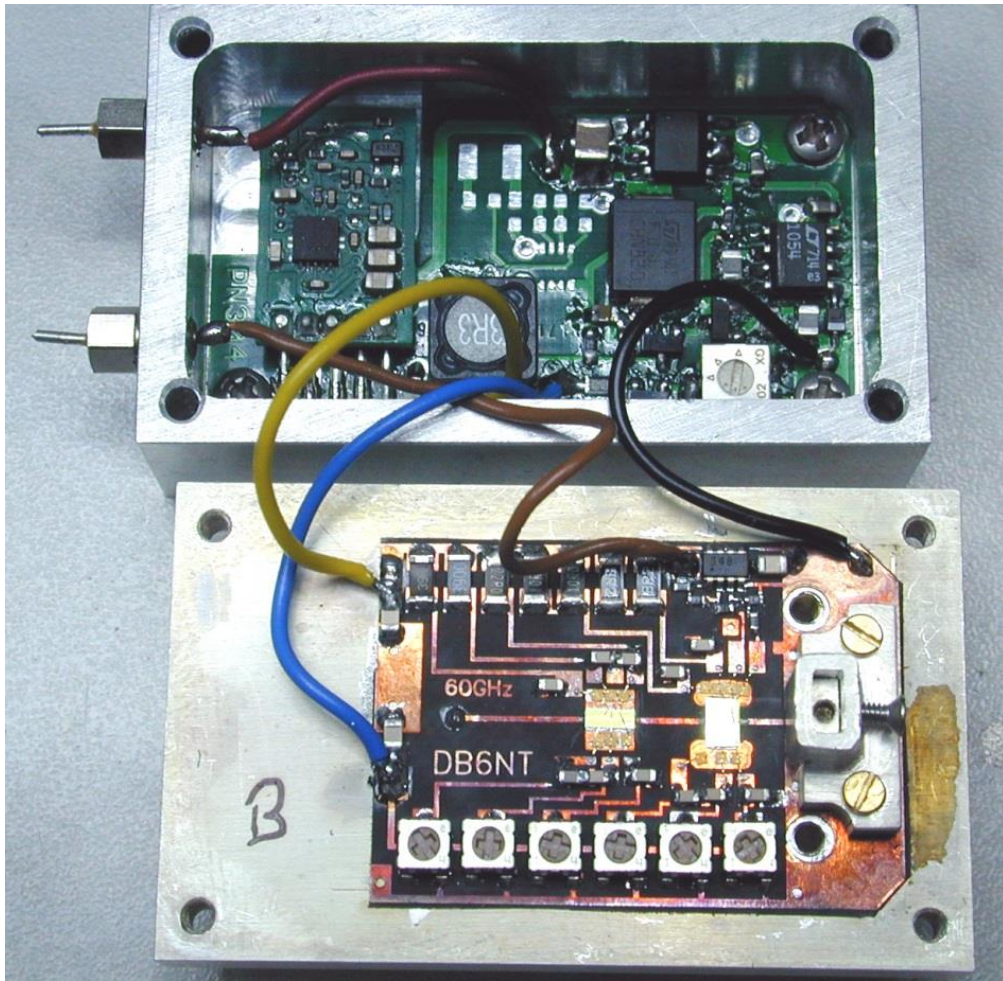
This oscillator produces a clean "low-jitter" and frequency-switchable signal. Furthermore, the module with 10 MHz (GPSDO) is controllable and has a built-in "CW Keyer".

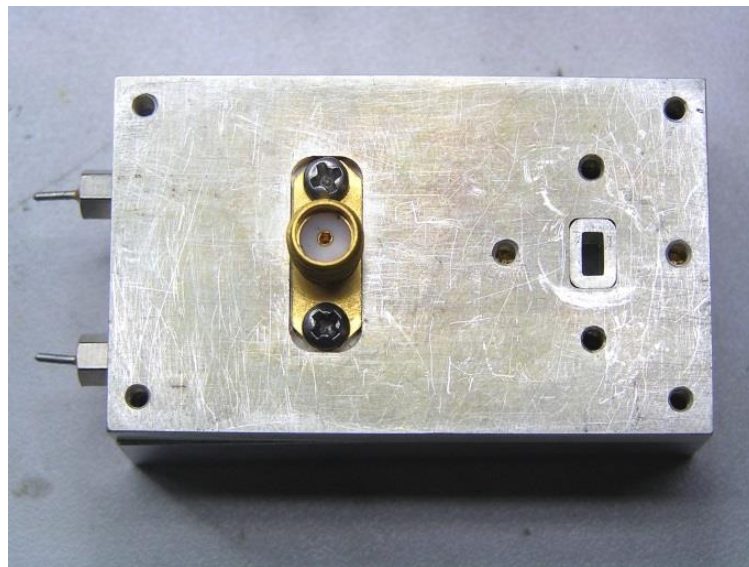
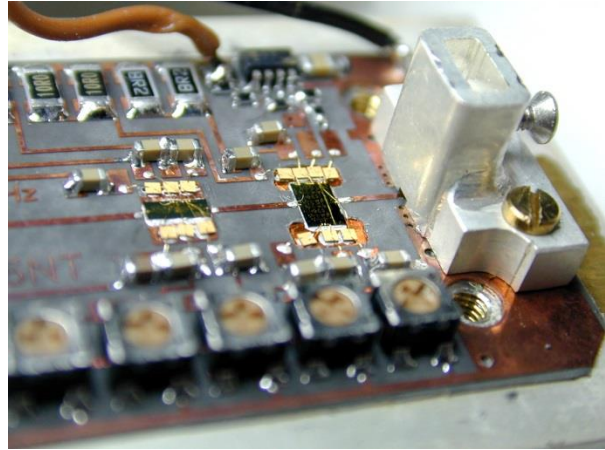


The voltage specifications are without HF control of the circuit.



There were built 3 units of this components, while the achieved RF output powers were comparable.





### **241 GHz signal generating:**

A CW transmitter using a diode frequency tripler for 241 GHz requires 80.640 GHz as its control frequency. In my internet research for suitable chips for this frequency, I found the six-fold **HMC1110** and the power amplifier **HMC8142** of the company **ANALOG DEVICES** from the **USA**.

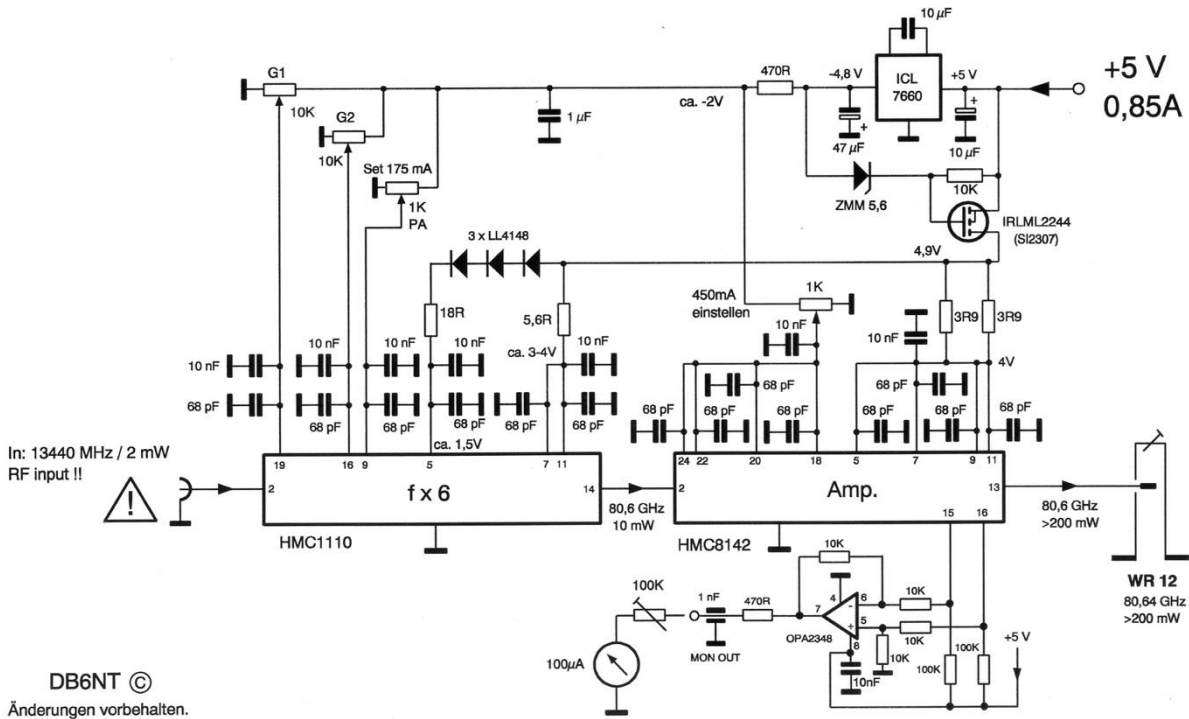
This combination promises an output power of 400 mW (P<sub>sat</sub>) with a drive of 2 mW at 13,440 GHz. The PCB is also made of RT5870 0.12mm material. The processing and the adjustment takes place as with the 60 GHz module described above.

### **Result:**

The output power reached was a maximum of 250 mW at 80.64 GHz. Unfortunately, the "data sheet performance" of 400 mW was not reached here either. There were 4 assemblies produced. The measured output powers of these specimens were always over 220 mW.

I think 220 mW is here a considerable LO performance for driving a frequency tripler.

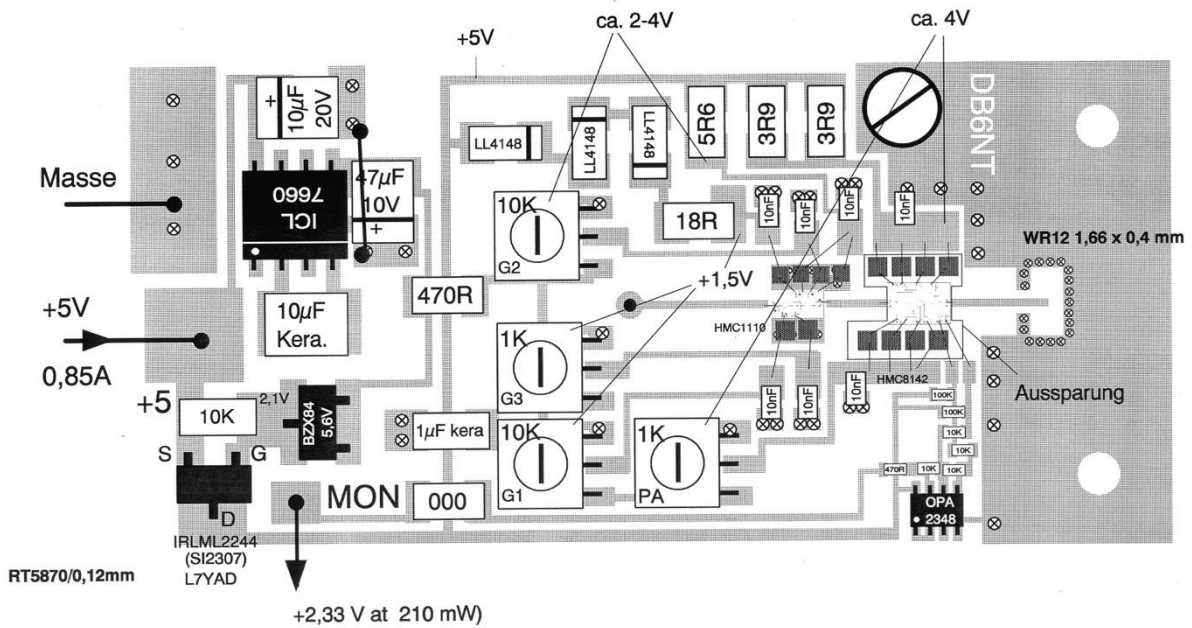
# 80,6 GHz LO DB6NT 02.2016

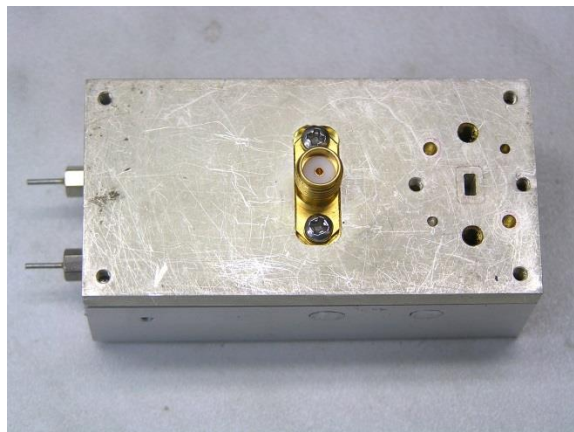
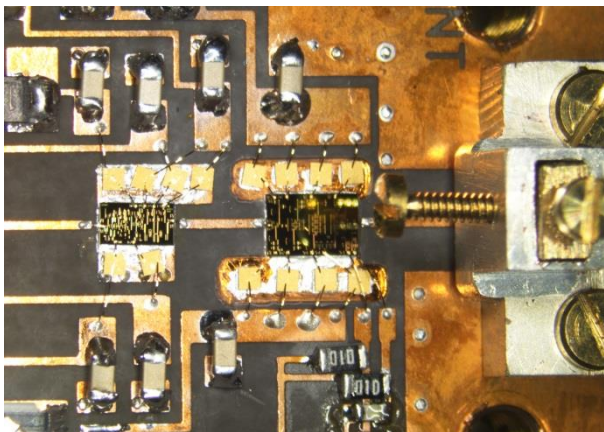
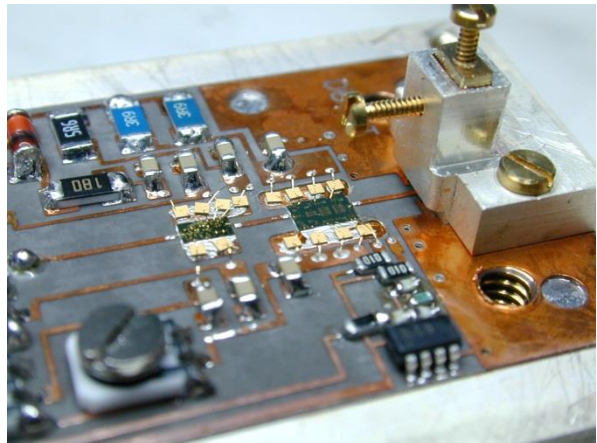
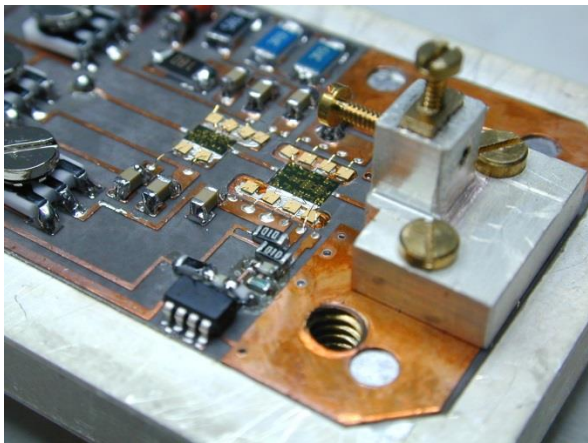
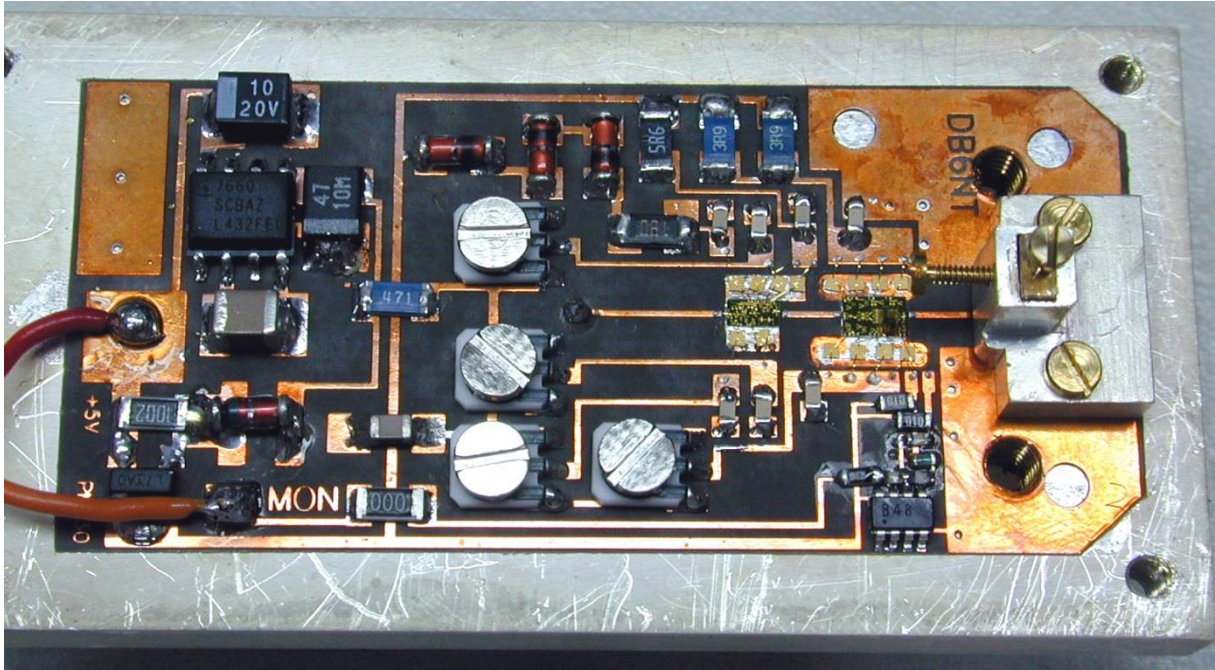


DB6NT ©  
Änderungen vorbehalten.  
Subject to alterations.

# 80,6 GHz LO DB6NT 01.2016

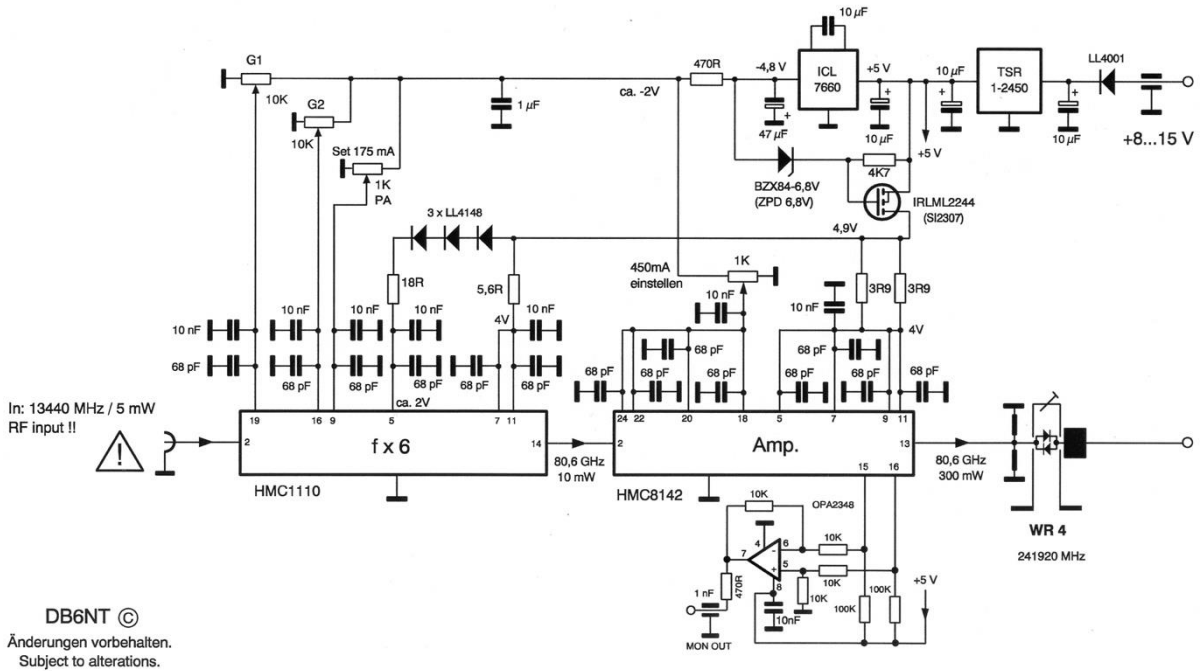
LO IN 13440 MHz 2 m. >200 mW out @80,64 GHz





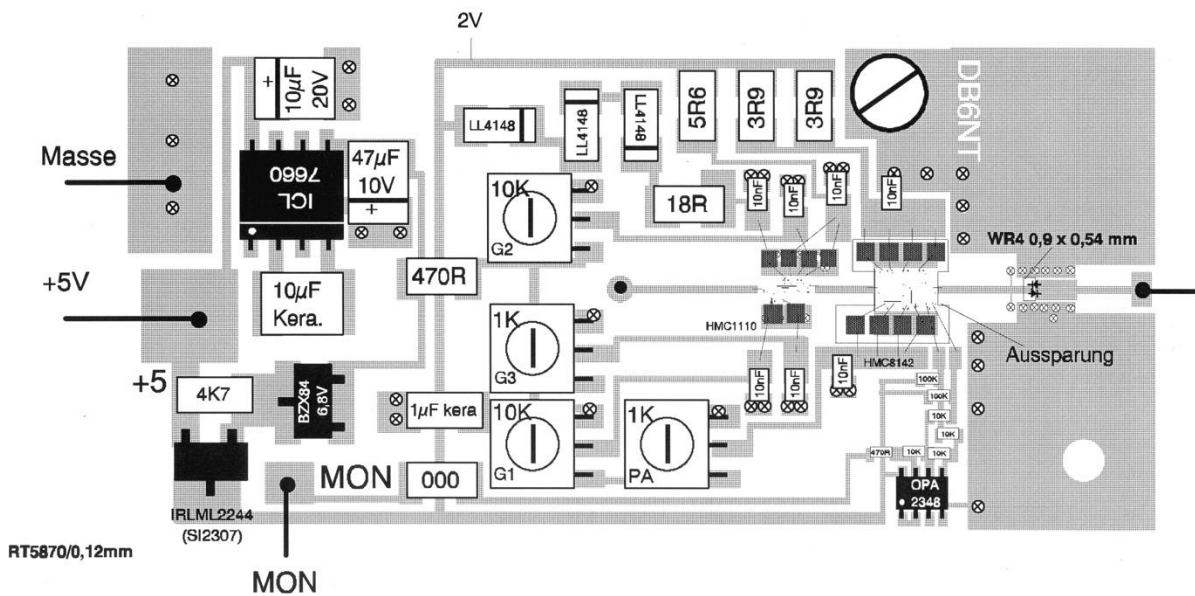
The following describes a variant of a "diode triplexer integrated on the PCB". First attempts were very encouraging. In this case, a "triple diode" of the company **ACST** was used. Unfortunately, no measured values can be published here, as we currently have no calibrated power meter available.

## 241 GHz Sender DB6NT 02.2016



As diodes for frequency tripling different variants can be used, for example Schottky diodes (type: single or antiparallel), multi-varactor diodes, etc.

## 241 GHz CW TX DB6NT 01.2016



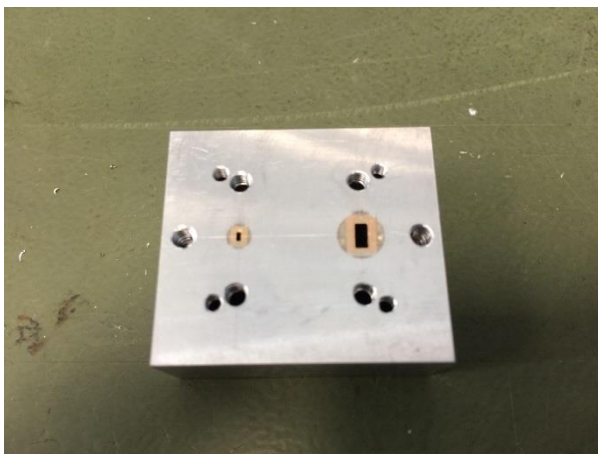
## Frequency tripler from 80 to 241 GHz

### Construction:

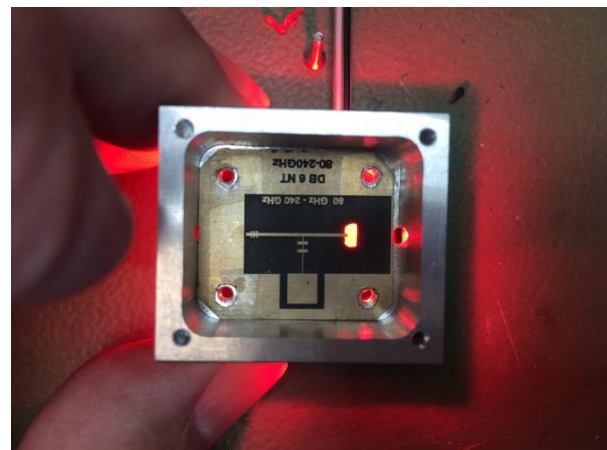
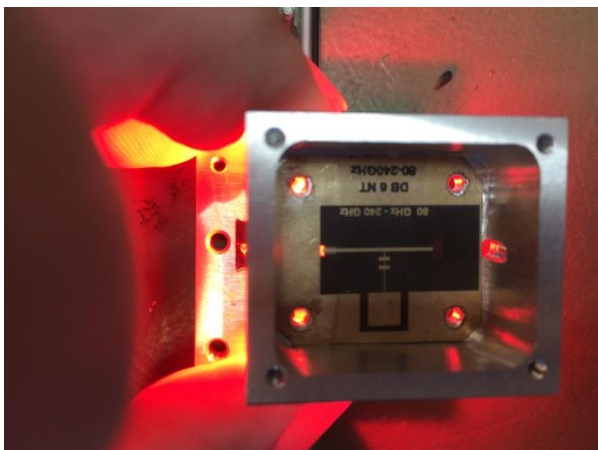
The mechanical structure is as simple as possible, because not everyone has the opportunity to perform super small and sophisticated milling.

The assembly takes place in a milled aluminum housing with inserted waveguides. First, the positions of the waveguides are marked on the circuit board with a grain and then drilled. The drill diameter is drilled about one tenth smaller than the waveguide diagonal.

As a result, the pressed-in copper waveguide later sits taut in the housing and is still glued with conductive adhesive. Protruding parts are removed after curing by over-milling. The holes for the flanges and the threads of the tuning screws for mounting the waveguides are also drilled. The tuning screws are "Microwave Tuning Elements" from **EXXWLIA**.

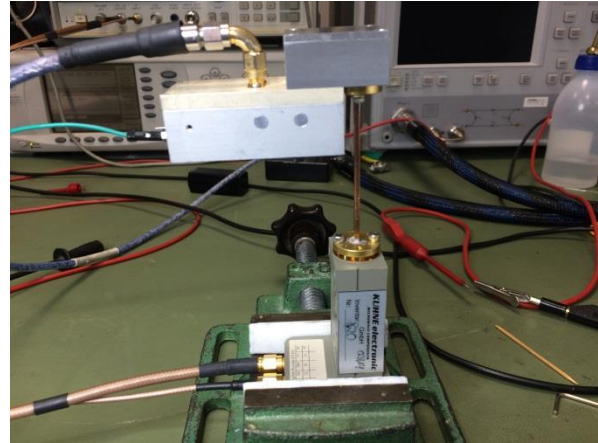
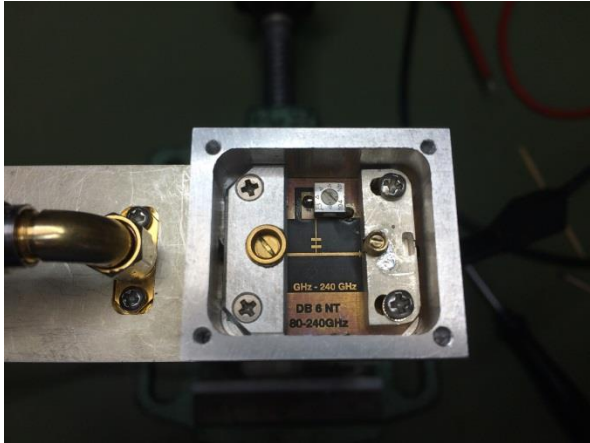


Then the circuit board is glued in with silver conductive adhesive. For optimal positioning, a red power LED is used as the light source. The light shining through the circuit board is clearly visible at the waveguide junctions.



In order to cure the adhesive, the housing is heated. Then I cleaned the PCB, glued the diode and mounted the shorts for the waveguides. Depending on the diode used, a potentiometer is soldered in to adjust the operating point. Schottky diodes require a small working resistance (<1K), varactor diodes require a high resistance (100 K) or an external voltage source.





The pictures show the assembly with 80 GHz LO driver and the mixing head HP11970W of the spectrum analyzer, which serves as a power indicator. The adjustment is done by mutual adjustment of the screws (waveguide transitions) and the adjustment of the operating point (potentiometer).

### **Results:**

First, an antiparallel diode **MACOM MA4E1318** was tested. These types of diodes are often used for broadband frequency tripler. A load resistor was not required because the diodes limit themselves. The output power was very modest. I attribute this to the rather high capacity of the diode which is manufactured for 80 GHz at the maximum.

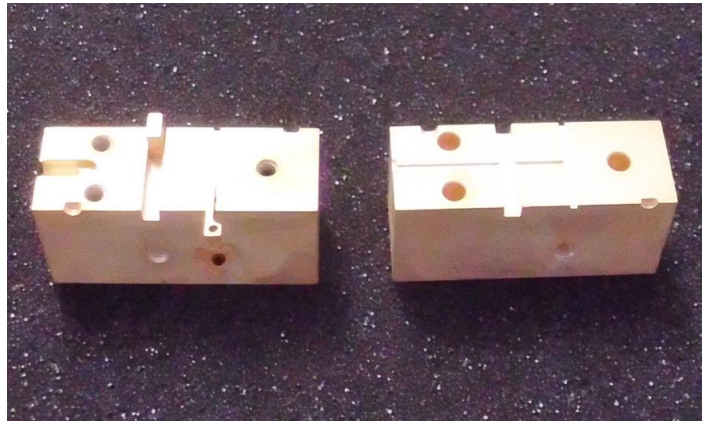
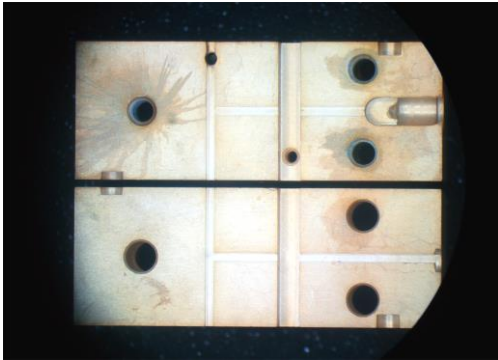
Now a varactor diode type. **A92220-1 (3A643A-3)** made by **SALUT-ELECS Ltd** of Russia is glued. This diode has a cutoff frequency of 3.6 THz. It requires a high working resistance of approx. 100K. The DC voltage that results when activated is 4.5V. The resulting output power was more than 10 dB greater than that with the previously measured MA diode.

Further experiments with other diodes will follow.

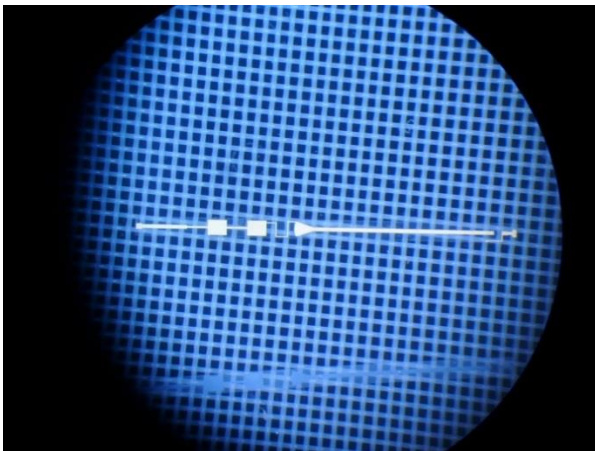
### **Here is the diode-tripler by Gert DG8EB**

#### **Construction:**

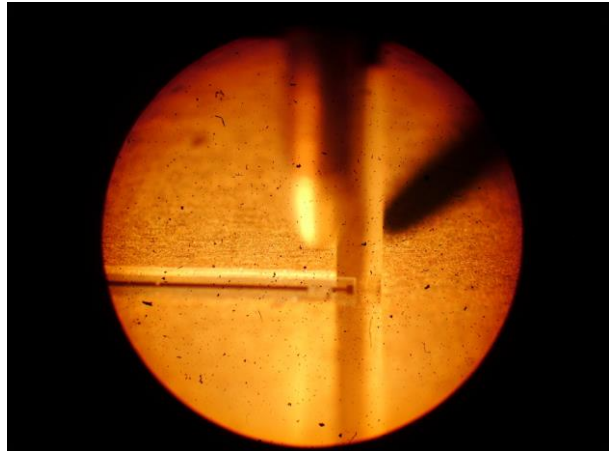
Thanks to the milled recesses in two brass blocks, the waveguides for coupling and decoupling are realized. Between the two waveguides, the printed circuit board with the microwave substrate and the diode is housed in a "trench". We got this substrate from Sigurd DL9MFV. Thank you Sigurd. With H20S silver conductive adhesive, the substrate and the diode is glued.



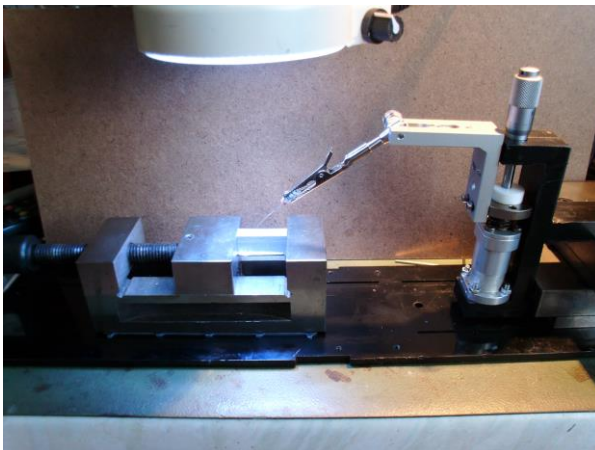
Here you can see the two halves of the brass block with the short-circuit slides of the waveguides.



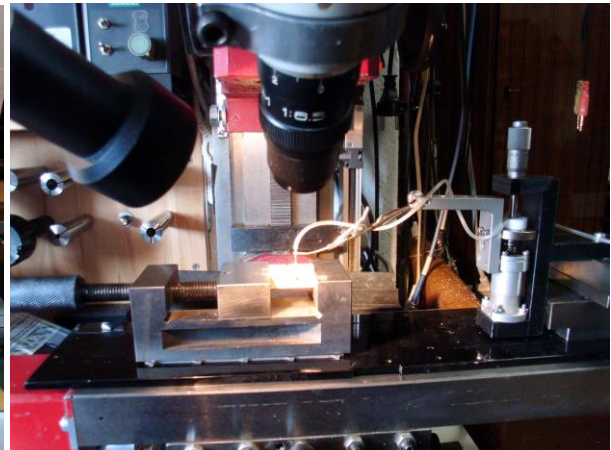
The substrate before mounting



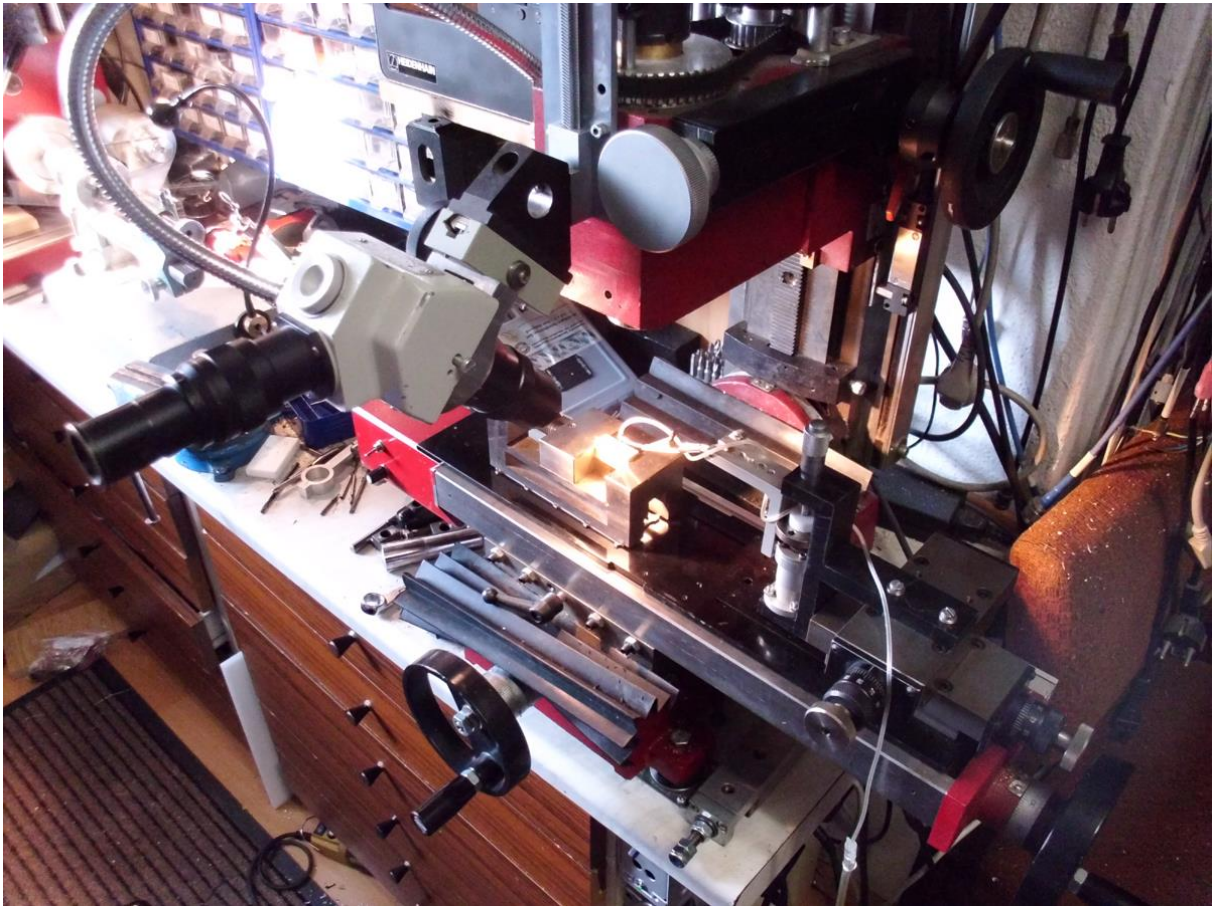
Diode is inserted



Self-made micromanipulator for positioning conductive adhesives and diodes.



Positioning of the diode with vacuum. Cannula 0.3 mm in diameter.



Here a "triple diode" of the company **ACST GmbH** was used. The operating point was set with a resistance of less than 1 K.

The output power achieved was about 8 dB greater than that of the **ELECS** diode. This is probably not only because of the diode but also justified by the excellent, almost professional structure.

Many thanks to my son **Matthias DK5NJ** for revision and translating.

#### **Sources and References:**

**DENIS BOULANGER:** Wire bonding to Soft Substrates:  
**Microwave Journal Feb.1990**

Technical data of **gXSB0019A** and **gAPZ0039A**  
<https://www.gotmic.se/>

Technical data of **HMC1110**  
<https://www.analog.com/media/en/technical-documentation/data-sheets/HMC1110.pdf>

Technical data of **HMC8142**  
<https://www.analog.com/media/en/technical-documentation/data-sheets/HMC8142.pdf>

**Sigurd Werner DL9MFV:** Oszillatorkaufbereitung für 122 GHz:  
Frequenzvervielfacher auf 61 GHz und Signalverstärkung  
**UKW- Berichte 1/2013**

**Sigurd Werner DL9MFV:** Frequenzverdoppler und subharmonischer Mischer für 122 GHz  
**UKW- Berichte 2/2013**

**Sigurd Werner DL9MFV:** Oszillatorkaufbereitung, passiver Frequenzverdreifacher und Mischer für 242 GHz  
**UKW- Berichte 1/2014**

**Sigurd Werner DL9MFV:** Verbesserte Frequenzverdoppler für 122 GHz  
**UKW- Berichte 3/2014**

**Sigurd Werner DL9MFV:** Neuer Frequenzverdreifacher und subharmonischer Mischer für 242 GHz  
**UKW- Berichte 1/2015**

**Sigurd Werner DL9MFV:** Frequenzverdoppler für 122 GHz im Zwei-Schalenaufbau  
**UKW- Berichte 3/2013**

**SALUT ELECS Ltd.** Diode Data:  
[http://www.db6nt.de/fileadmin/userfiles/\\_pdf/download\\_archiv/Elecs.pdf](http://www.db6nt.de/fileadmin/userfiles/_pdf/download_archiv/Elecs.pdf)

**MACOM** Diode **MA46H146:**  
<https://cdn.macom.com/datasheets/MAVR-000146.pdf>

**MACOM** Diode **MA4E1310:**  
<https://cdn.macom.com/datasheets/MA4E1310.pdf>

**Teledyne** GaAs Millimeter Wave/Sub-Millimeter Wave Schottky Diodes:  
<http://www.teledyne-si.com/products-and-services/scientific-company/gaas-millimeter-wave-sub-millimeter-wave-schottky-diodes>

**ACST GmbH** Diodes: <http://www.acst.de/>  
**Virginia Diodes, Inc.:** <https://vadiodes.com/en/products-6/w-and-g-band-diodes>  
**Teratech** Diodes: <http://www.teratechcomponents.com/>

**Teledyne** 241 GHz MMIC-Power Amplifier:  
<http://www.teledyne-si.com/products-and-services/scientific-company/mmic-power-amplifier>

**EXXWLIA** Microwave Tuning Elements  
<http://www.exxelia.com/en/product/detail/598/at-6926-x-sl-rohs>

**DB6NT** Download Archive: <http://www.db6nt.de/download-archiv.html>