Laser Communication Terminal: Product Status and Industrialization Process

Herwig Zech, Frank Heine, Matthias Motzigenmba
TESAT, Backnang, Germany, Herwig.Zech@tesat.de,

Abstract—**Laser Communication Terminals have left the status of R&D programs and are now applied in commercial satellite communication systems. The European Data Relay System (EDRS) is based on optical intersatellite links at a data rate of 1.8 Gbps for its commercial data relay service. In this paper, the key design elements of the Laser Communication Terminal (LCT) applied for EDRS are presented and the most important performance parameters are given. An overview of the status of the current LCT programs will be presented. The next steps involve the further industrialization of the LCT. Targets are streamlining the integration flow, stabilizing the supply chain and to seek for design modifications within the qualification boundary conditions based on available LCT AIT experiences. The modular LCT design ensures that the heritage derived from the EDRS LCT can be transferred to other applications for the laser communication terminals. The modular design allows to spin off parts of the LCT as standalone products to further broaden the range of applications. The status of this industrialization process is given.**

Keywords— Laser Communication Terminal; European Data Relay System; Optical Intersatellite Links

I. INTRODUCTION

Laser communications has been considered for space applications since the invention of the laser. The attraction has always been the fact that wavelengths in the optical regime are shorter by a factor of 10000 compared to radio frequency wavelengths. The shorter wavelength results in a smaller diffraction spot compared to traditional radio frequency communication options, leading to smaller optics versus larger RF antennas. The narrow optical beam width make optical communication the ideal candidate for point to point links. The vulnerability to link interference through a third party is drastically reduced. Jamming a coherent homodyne optical inter-satellite link is almost impossible. In addition, there are no regulations for the use of the optical spectrum, as can be found in the RF communication bands. This makes the planning of the intersatellite links much easier. Another advantage of optical communication links results from the optical carrier frequency that is again a factor of 10000 higher than in conventional RF. With this high carrier frequencies combined with the modulation capabilities in the optical regime, communication data rates in the high Gbps regime can be realized that are not possible with standard RF technology. The increased communication data rate capability matches the continuously improving capability of instruments on board of e.g. earth observation spacecrafts (S/C). The amount of data generated on board is asking for increased data communication capabilities that can be easily matched by optical communication technologies.

There had been a lot of research work and demonstration experiments in the past on optical communication in space that have been discussed in detail in various forums like the ICSOS. With the introduction of the European Data Relay System (EDRS) [1], the door opened for the first commercial use of optical intersatellite links in space.

In this paper, the design principles of the Laser Communication Terminal (LCT) used in EDRS are shown and the status of the LCTs in production is given. In addition, an overview of the commercial LCT production line is provided together with a brief status of the ongoing industrialization activities. Finally, the topic of standardization is adressed.

II. LCT DESIGN PRINCIPLES

The year 2007 saw the launch of two Low Earth Orbit (LEO) S/Cs, both having a TESAT LCT of the first generation on board. Since then, LEO to LEO communication links and LEO to ground communication links were exercised providing a lot of knowledge on optical communication links in space [2] [3] [4].

The use of optical communication links in data relay systems offers the unique advantages that, compared to traditional ground link concepts, a much higher coverage of the LEO S/Cs can be reached and that a near realtime communication at high data rates can be achieved. EDRS is a GEO data relay system operated at a data rate of up to 1,8 Gbps. To supply EDRS, the LCT design of the first generation was enhanced to cover LEO to GEO distances [5][6]. Table 1 has the technical key parameters of both LCT generations.

TABLE I. LCT KEY PARAMETERS

	LCT Key Parameters	
	1st generation LEO to LEO	***2nd generation LEO to GEO***
Range	5100 km	45000 km
Data Rate	5,625 Gbps	1,8 Gbps
Data format	1064 nm, BPSK homodyne	1064 BPSK homodyne
Transmit Power	0,7 W	2,2 W
Telescope diameter	125 mm	135 mm
Mass	35 kg	53 kg
Power consumption	120 W max	160 W max
Dimensions	0,5 x 0,5 x 0,6 m	0,6 x 0,6 x 0,6 m

The block diagram in Figure 1 illustrates the LCT design principle. The LCT operates at 1064 nm wavelength based on Nd:YAG technology. For best sensitivity, a coherent BPSK modulation scheme was chosen applying a coherent receiver with a local oscillator laser. A bidirectional communication link operating at 1,8 Gbps user data rate in both directions is implemented. The transmit and receive path are sharing the telescope, separation is achieved by polarization and frequency. The communication beam is also used for acquisition purposes applying a spiral scanning scheme and thus avoiding a beacon.

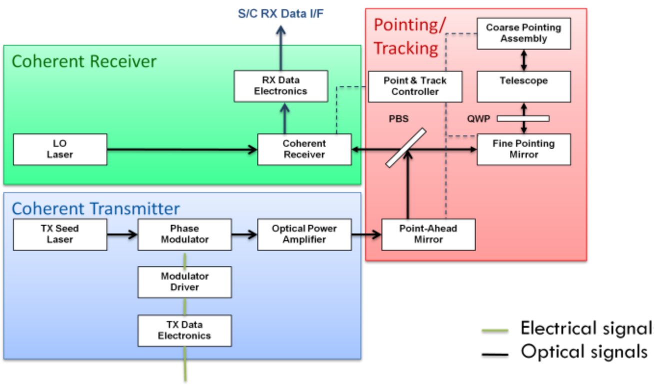

Fig. 1. LCT block diagram.

Figure 2 shows the second generation LCT with its Coarse Pointing Assembly (CPA) in unparked condition. The CPA is the major beam steering mechanism that allows beam pointing towards a complete hemisphere.

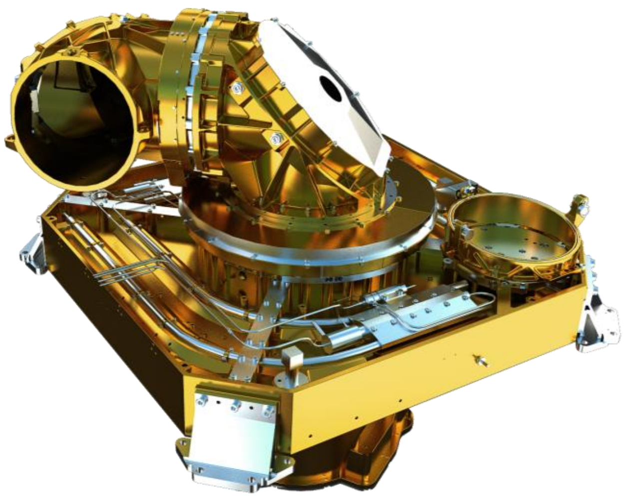

Fig. 2. 2nd generation LCT.

The core design of the LCT for LEO S/Cs and for GEO S/Cs are the same except for S/C interface and orbit-typical adaptations. This offers advantages in the LCT production, as many subunits from LEO and GEO LCTs are identical.

III. Overview of LCT Projects

In this section, a brief overview of the running LCT projects of the second generation is given. The first LCT of the second generation was mounted onto the Alphasat S/C. Alphasat was launched in July 2013 and is now located in its GEO orbital position. The commissioning of the LCT on board of Alphasat is ongoing. First ground link pointing and tracking tests with an optical ground station located at Tenerife were performed successfully.

The first LEO S/C having an LCT of the second generation on board, is Sentinel 1A, see Fig. 3. The Sentinel 1A LEO S/C is foreseen to be the first LEO S/C customer for the EDRS data relay system. Sentinel 1A is planned to get launched in April 2014. LEO to GEO optical intersatellite links between the LCTs on Sentinel 1A and Alphasat are foreseen later in 2014. The latest status of the in-orbit activities for Alphasat and Sentinel 1A will be given in the presentation at ICSOS.

Besides Alphasat and Sentinel 1A, their respective LCTs being on board of the S/C and in orbit or close to launch, there are a number of additional LCTs in production at the moment. The LCTs for the GEO S/Cs EDRS A and C form the GEO nodes of the EDRS system. LCTs for the LEO S/Cs Sentinel 2A, Sentinel 1B and Sentinel 2B are currently under production.

In total, 7 LCTs of the second generation, for both LEO and GEO orbit are currently either delivered or in production. Negotiations on the production of further LCTs are ongoing.

Besides the LCT projects with the target of HW delivery to the S/Cs, TESAT is involved in the development, test and operation of the EDRS data relay system. The operational concepts are developed together with all involved parties in charge of S/C operations, ground station operations and service provisioning. In the full EDRS configuration, up to hundreds of optical data relay links per day from several LEO Earth Observation space crafts or UAVs in a commercial environment are foreseen.

Fig. 3. LCT integrated on Sentinel 1A S/C, (picture courtesy of TAS-I).

IV. LCT Production Overview

As mentioned in the previous section, 7 LCTs of the second generation LCT are already delivered to the customers or are in production at TESAT at the moment. Since the LCT core design is the same for both LEO and GEO LCTs, most of the LCT subunits are the same and can be manufactured with the same manufacturing parameters at TESAT or at the suppliers. For the LCT integration, a 400 square meter class 100 cleanroom (ISO 5) has been set up, see Fig 4. Three thermo vacuum chambers with optical test beds are available. In total two parallel manufacturing lines are available for the LCT integration, supported by trained personal.

The subunit and LCT level tests have been automated to a high degree to facilitate the AIT process. A permanent lessons learned program is set up to continuously optimize the AIT flow. Obsolete parts management practices are in place to assure a stable production. Long-term contracts with key suppliers are established to secure the supply chain.

Several LCT Subunits can be supplied as stand alone units independent from the LCT. The laser source at 1064 nm can be used for applications requiring space qualified, highly stable laser sources. The optical encoder specifically developed for the LCT Coarse Pointing Assembly [7] can be used in a wide range of high precision encoder applications in space. With these standalone units, also other applications can benefit from the space qualification activities set up for the LCT. In addition the range of production is enhanced widening the possibilities of subunit lot productions.

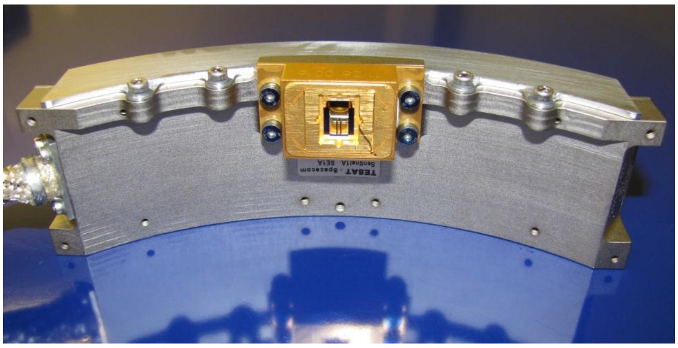

Fig. 4. Optical Encoder

V. Standardization

To facilitate global interoperability of optical intersatellite links, a standardization of the optical interface is deemed necessary. By doing so, e.g. a global GEO data relay system like EDRS can be opened up to a large basis of customer earth observations S/Cs or Unmanned Aerial Vehicles (UAVs). The definition of a standardized LCT interface assures the interoperability between various S/Cs and UAVs together with the corresponding ground stations. Therefore, TESAT is participating in the standardization activities for optical links started in 2013 by the Consultative Committee for Space Data Systems (CCSDS). TESAT and DLR in co-operation with ESA agreed to generate the necessary input for the standardization blue and green books..

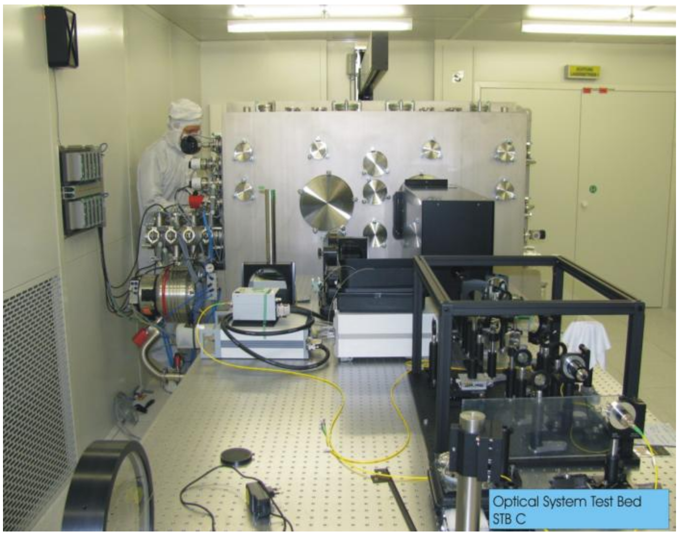

Fig. 5. Class 100 (ISO 5) cleanroom- showing thermo vacuum chamber (background) for the LCT and wafe front and communication analization equipment located in the front.

VI. Summary

Laser Communication Terminals have left the status of R&D programs and are now applied in commercial satellite communication systems. The European Data Relay System (EDRS) is relying on optical intersatellite links at a data rate of 1.8 Gbps for its commercial data relay service. This first commercial application of Laser Communication in Space is a major breakthrough for the widespread introduction of this technology in space. A full production line supporting two parallel LCT AIT activities are set up and running at TESAT. In the paper, the status of LCT production and the related industrialization process is given. TESAT is supporting the standardization activities for optical intersatellite links in the frame of the CCSDS standardization.

Acknowledgment

The LCT development and in-orbit verification is supported by the German Space Agency DLR /BMWi under 50YH0202, 50YH0632, 50YH0801 and 50YH0802. The authors gratefully acknowledge the continuous support by DLR and by ESA.

REFERENCES

[1] M. Witting, et al, "Status of the European Data Relay Satelitte System " Proc. of ICSOS(2012)

[2] B. Smutny, "5.625 Gbps optical inter-satellite communication link verified in-orbit", Proc. of the Ka and Broadband Communications Conference (2008).

[3] Gregory, M., Heine, F., Kaempfner, H., Lange, R., Lutzer, M., and Meyer, R., "Coherent inter-satellite and satellite-ground laser links," in [Proc. SPIE, Free-Space Laser Communication Technologies XXIII], 7923, 792303–1 792303–8 (2011).

[4] M. Gregory 3 Years Coherent Space to Ground Links: performance results and outlook for the optical ground station equipped with adaptive optics, Proc SPIE 03/2013; DOI:10.1117/12.

[5] K. Boehmer, "Laser Communication Terminals for the European Data Relay System", Proc. of SPIE 8246 (2012).

[6] G. Muehlnikel, "The Alphasat GEO Laser Communication Terminal flight acceptance tests", Proc.ICSOS, 13-1, (2012).

[7] M. Reinhardt et al. "High Precision Encodes for GEO Space Applications", Applications of Lasers for Sensing & Free Space Communication (LS&C), (2013)