Fully Photonic Wireless Link for Transmission of Synchronization Signals

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Abstract. *Rapid industrialization and increasing demand of business tools for high-speed communications supports the request for optical communications in free space. Copper cables and related technologies such as cable modems and Digital Subscriber Line (DSL) are common in existing networks, but do not meet the bandwidth requirement in the future, which opens the door to optical wireless communication technologies. Research in links for optical wireless communication (Infra Red Line of Sight, IR LOS) working in the atmosphere is due to the wide support of its development on the world market. Optical wireless communications research is currently focused on increasing the transmission quality of data links. A promising new trend in data connection through IR LOS includes the transfer of accurate time synchronization pulses (time transmission). The article presents problems of modeling and design of a transmitter and receiver with a fully photonic concept. The analysis of the power levels at the link and drawn a model for determining the connection losses at the receiver caused by optical coupling between a Schmidt-Cassegrain telescope and the receiving optical fiber is shown.*

Keywords

Optical wireless communications, fully photonic link, atmospheric phenomena, angle of arrival

1. Introduction

Optical Wireless Communication (OWC) is a communication using an optical wave, which is propagated through an atmospheric, cosmic or water environment to carry information. Optical power is usually divided into one or more optical beams. A wavelength-division multiplexing (WDM) technique could be used to multiplex a number of optical carriers onto a single optical wave. OWC technology is usually used as an alternative to optical fiber links, radio links (radio-relay and satellite communication) and acoustic links (underwater communication). The usage of OWC links is advantageous in situations where fiber links and radio links could not be used for some reasons. The application of an OWC link is not only for communication purposes but can also be used as a sensor (e.g. LIDAR, distance meter ...).

The main benefits of OWC technology are

- Extremely secure for government or military use, due to its narrow pencil like beam
- High bit rate (up to 1 Tbit/s)
- License-free operation (almost worldwide)
- Relatively small dimensions and easy deployment of communication terminals (e.g. in the frame of a satellite)

For the reason that OWC link performance is dependent on weather conditions, there are many publications which suggest methods for suppressing the effects induced by atmosphere. For seeking these methods one has to keep in mind parameters of the link and statistic properties of the transmission medium (e.g. water, atmosphere . . .). Because a "general" OWC link does not exist, it is not correct to list the general parameters of an OWC link. Each OWC link has its particular purpose and works with a certain modulation and coding techniques.

High data rates, low BER (Bit Error Rate), and high availability and reliability are expected from OWC data links. These parameters are the main factors of our research. For the availability estimation of the IR LOS data link a complex model was created; the properties of the atmospheric transmission medium were studied in [1]; a hybrid link was built and tested [2] and the optimal distribution of the optical intensity within a laser beam was defined [3].

Different theoretical models and experiments have been published in available literature, however, usually there are problems with correctly interpretating the results. For instance, measured attenuation is considered to be caused by the atmosphere; however, it could be caused by deformation of the console due to sunlight or wind. Even these problems are challenging for the authors of this paper.

2. Application

There are a number of methods for decreasing the dependence of the terrestrial IR OWC links on the atmosphere:

- Diversity technique (space, time, wavelength and coding)
- Adaptive optics
- Beam shaping
- Advanced signal processing
- Hybrid links

Although some methods are very efficient and significantly improve link qualitative parameters, their implementation is very difficult and they are unaffordable.

The research of OWC links is presently focused on enhancing testing links which are used to measure the effect of the atmosphere on the link, and on increasing the quality of the data links. The transmission of highly stable optical frequency usable in measurement of time, frequency and length belongs among new prospective trends in this area. The requirements listed above are fulfilled by using the concept of the fully photonic link with the exclusion of electrical blocks in the signal path [4].

The benefit of the fully photonic concept is mainly in speeding up the data transfer and in the possibility of applying the method of optical WDM both for testing purposes (atmospheric influence on beams with different wavelengths) and for transmitting coherent optical waves. A drawback of the fully photonic approach is difficulties in alignment of used optical elements [5].

The research of OWC systems done by the authors of this paper is focused on data and testing links in the waveband 1550 nm. The realization of an OWC terminal with fully photonic parts is studied. This concept allows, e.g., to remove blocks performing E/O conversion, to place electric parts in the indoor unit which is not so affected by strong atmospheric changes, to create a multi-mode beam for reducing scintillation, to use WDM for increasing transmission capacity, to apply EDFA for improving the energetic balance of the link, to use fiber filters, etc.

The application of this concept allows us to transmit precise time synchronization pulses which is useful for scientific laboratories to synchronize their experiments.

3. Matrix Optics Model of the Fully Photonics Link

3.1 Transmitter

The fully photonic concept of the transmitter offers many possibilities in improving optical wireless communication. The transmitted beam may include multiple optical channels obtained by using the WDM technique.

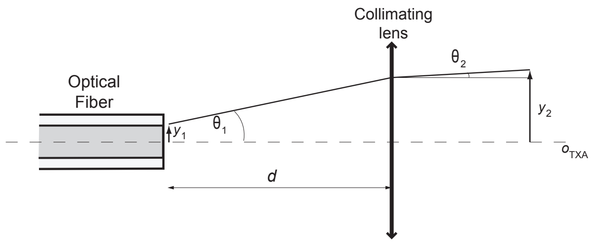

Fig. 1. Model of the FPT.

The purpose of the Fully Photonic Transmitter (FPT) is to create a transmitted optical beam by an optical fiber irradiating the transmitting lens (achromatic doublet lens). If the multimode fiber (plastic or glass) is used as a final fiber, the optical intensity distribution in the transmitted beam will generate a so-called "top-hat" beam [5], which is more resistant to the negative effects of atmospheric turbulence in comparison with the standard Gaussian beam.

For the sake of simplicity, a single mode fiber with core diameter 10 μm and numerical aperture (NA) was used as the final fiber in our model. Owing to the energetic balance of the link, the divergence of the transmitted optical beam is required in the range of 70 μrad - 15 mrad. For modeling the FPT function, it is sufficient to apply the matrix optics methods.

The translation matrix describing the free space propagation of the optical ray through the distance d between the output aperture of the optical fiber and principal plane of the transmitting optical system (achromatic doublet lens) is expressed as follows [7]

$$\mathbf{M_T} = \begin{bmatrix} 1 & d \\ 0 & 1 \end{bmatrix}. \quad (1)$$

The transmitting optical system (Fig. 1) is modeled as a thin ideal lens with focal length f_{TXA}. Propagation of the optical ray through this lens is described by the refraction matrix $\mathbf{M_R}$

$$\mathbf{M_R} = \begin{bmatrix} 1 & 0 \\ -\frac{1}{f_{\mathrm{TXA}}} & 1 \end{bmatrix}. \quad (2)$$

The resulting transfer matrix, between the output aperture of the optical fiber and output plane of the achromatic doublet lens, could be expressed by transfer matrix (1) and refraction matrix (2). The output ray parameters at the output of the collimating lens (transmitting aperture) are given by (Fig. 1)

$$\begin{bmatrix} y_2 \\ \theta_2 \end{bmatrix} = \mathbf{M_R}\,\mathbf{M_T} \begin{bmatrix} y_1 \\ \theta_1 \end{bmatrix}. \quad (3)$$

Therefore, parameters of the transmitted ray (y_j and θ_j, j = 1, 2) can characterize the parameters of the transmitted beam: distance of the ray from the optical axis y_j corresponds to beam radius, and angle between the ray and optical axis θ_j agree with beam divergence. After substituting matrices (1) and (2) into equation (3) we get the relations for beam radius y_2 and beam divergence θ_2

$$y_2 = y_1 + d\,\theta_1, \tag{4}$$

$$\theta_2 = -\frac{y_1}{f_{TXA}} + \theta_1 \left(\frac{d}{f_{TXA}} - 1 \right). \tag{5}$$

After substituting the angle θ_1, which is given by the numerical aperture of the transmitting fiber and core radius of the transmitting fiber y_1, into (4) and (5) we get the distance of the principal plane of the collimating lens from the optical fiber end face approximately $d = 71$ mm. An achromatic doublet lens NEWPORT PAC19AR.16 with focal length $f_{TXA} = 75$ mm and diameter $D_{TXA} = 25.4$ mm, which is suitable for the transmitting optical system, was chosen as the collimating lens from commercially available lenses.

3.2 Receiver

The purpose of the Fully Photonic Receiver (FPR) is to lead as many transmitted photons propagated in free space as possible into the core of the receiving optical fiber. The fully photonic concept for the receiver makes the transfer speed higher and makes it possible to transmit the entire optical signal including the phase.

The Schmidt-Cassegrain telescope was selected to receive optical waves due to its properties (compactness and mirror technology). The concept is shown in Fig. 2. The plane wave with symmetrical Gaussian distribution of optical intensity captured by the Schmidt - Cassegrain telescope is collimated by the aspheric collimation lens and guided to the GRIN lens, which is connected to an optical fiber at its output (see Fig. 2). The outgoing collimated optical wave from the aspherical lens is achieved by tuning the focal length f_{tel} of the Schmidt-Cassegrain telescope [6].

The FPR model (Fig. 3) was created using matrix optics methods. The light incoming on the receiving aperture of the telescope (RXA) under angle θ_i is focused to a point Q (shifted from the optical axis o_{RXA}) on the plane of the receiving optical fiber under angle $\mathbf{m_a}\theta_i$.

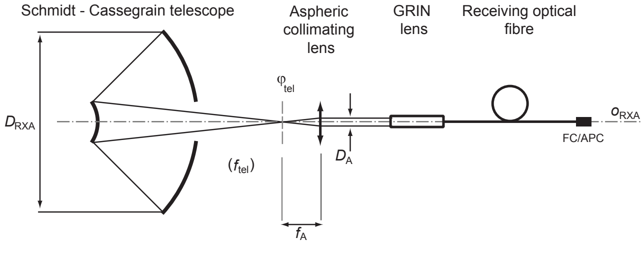

Fig. 2. Model of the FPR. D_{RXA} diameter of the receiver aperture; φ_{tel} - focal plane of the Schmidt - Cassegrain telescope; f_{tel} focal length of the Schmidt - Cassegrain telescope; f_A – focal length of the aspherical collimating lens; D_A – diameter of the outgoing beam from the aspherical collimating lens; FC/APC – fiber connector; o_{RXA} – optical axis of the FPR.

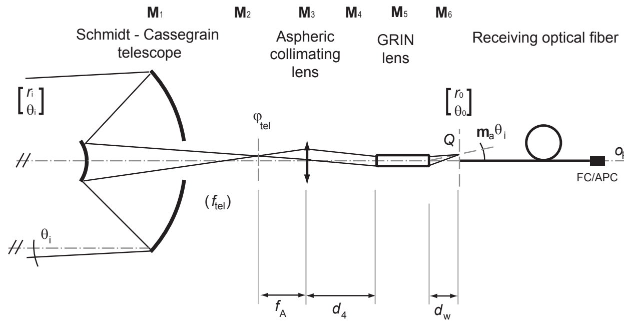

Fig. 3. The model used for designing and the basic FPR parameters determination. d_4 – distance between the aspheric lens and GRIN lens, d_w - working distance of the GRIN lens, $\mathbf{m_a}$ – angular magnification of the telescope, θ_i - angle the ray makes with the axis at the input aperture of the receiver, θ_0 - angle the ray makes with the axis at the input plane of the receiving fiber ($\theta_0 = \mathbf{m_a}\,\theta_i$) and r_0 - distance between Q and o_{RXA}.

In order to get the whole ray matrix optics of the system, the Schmidt-Cassegrain telescope is modeled as a thin positive lens (receiving lens) with refraction the matrix

$$\mathbf{M_1} = \begin{bmatrix} 1 & 0 \\ -\frac{1}{f_{tel}} & 1 \end{bmatrix}. \tag{6}$$

The ray transfer between the principal plane of the receiving lens and the principal plane of the apsherical lens is expressed by the translation matrix

$$\mathbf{M_2} = \begin{bmatrix} 1 & f_{tel} + f_A \\ 0 & 1 \end{bmatrix}. \tag{7}$$

For the ray transfer matrix of the aspherical lens it is possible to write

$$\mathbf{M_3} = \begin{bmatrix} 1 & 0 \\ -\frac{1}{f_A} & 1 \end{bmatrix}. \tag{8}$$

The distance between the principal plane of the aspherical lens and the input aperture of the GRIN lens d_4 is included in the translation matrix $\mathbf{M_4}$

$$\mathbf{M_4} = \begin{bmatrix} 1 & d_4 \\ 0 & 1 \end{bmatrix}. \tag{9}$$

The GRIN lens refraction matrix can be expressed as follows [8]

$$\mathbf{M_5} = \begin{bmatrix} \cos\left(g\, l_g\right) & \frac{1}{g\, n_g} \sin\left(g\, l_g\right) \\ g\, n_g \sin\left(g\, l_g\right) & \cos\left(g\, l_g\right) \end{bmatrix} \tag{10}$$

where g is gradient constant, l_g is length and n_g is refraction index at the center of the GRIN lens. The fiber is placed at the working distance of the GRIN lens (see Fig. 3). The working distance d_w is set by the manufacturer of the GRIN lens and is represented by the following translation matrix

$$\mathbf{M_6} = \begin{bmatrix} 1 & d_w \\ 0 & 1 \end{bmatrix}. \tag{11}$$

The ray transfer matrix of the complete receiving optical system $\mathbf{M_{RXA}}$ is given by multiplying all the elementary matrices in the correct order

$$\mathbf{M_{RXA}} = \mathbf{M_6}\,\mathbf{M_5}\,\mathbf{M_4}\,\mathbf{M_3}\,\mathbf{M_2}\,\mathbf{M_1}. \tag{12}$$

After rearrangement we obtain

$$\mathbf{M_{RXA}} = \begin{bmatrix} A_R & B_R \\ C_R & D_R \end{bmatrix} \tag{13}$$

where elements of the matrix are

$$A_R = -\frac{f_A\left(\cos\left(gl_g\right)\right) - d_w g n_g \sin\left(gl_g\right)}{f_{tel}}, \tag{14}$$

$$B_R = \left(\cos\left(gl_g\right) - d_w g n_g \sin\left(gl_g\right)\right)$$
$$\left[f_A - \frac{f_{tel}\left(d_3 - f_A\right)}{f_A}\right] \frac{f_{tel}\left(\frac{\sin\left(gl_g\right)}{g} + n_g d_w \cos\left(gl_g\right)\right)}{f_A n_g}, \tag{15}$$

$$C_R = \frac{f_A g n_g \sin\left(gl_g\right)}{f_{tel}}, \tag{16}$$

$$D_R = -\frac{f_{tel}\cos\left(gl_g\right)}{f_A} - g n_g \sin\left(gl_g\right)\left[f_A - \frac{f_{tel}\left(d_3 - f_A\right)}{f_A}\right]. \tag{17}$$

The parameters of the optical ray at the input plane of the receiving optical fiber (distance from the axis r_0 and angle θ_0 the ray makes with the axis o_{RXA}) can be derived from the transfer matrix of the complete optical system $\mathbf{M_{RXA}}$.

According to the law of matrix optics, one can write

$$\mathbf{K_0} = \mathbf{M_{RXA}}\mathbf{K_i} \tag{18}$$

where $\mathbf{K_i} = \begin{bmatrix} r_i \\ \theta_i \end{bmatrix}$ is input ray vector at the receiving aperture of the Schmidt-Cassegrain telescope and $\mathbf{K_0} = \begin{bmatrix} r_0 \\ \theta_0 \end{bmatrix}$ is the output ray vector at the input plane of the receiving optical fiber.

From the obtained relations, it is possible to calculate crucial parameters and make a design of the FPR. The coefficient B_R in (13) expresses the ratio

$$B_R = \frac{r_0}{\theta_i} \tag{19}$$

at $r_i = 0$. Therefore from this relation expression for r_0 goes:

$$r_0 = B_R\,\theta_i \tag{20}$$

where B_R is the element of the refraction matrix of the whole optical system (15).

Let´s assume that r_0 should not exceed the radius of the input aperture of the receiving fiber w_F, then the maximal angular ray misalignment at the input aperture of the receiver $\theta_{i,max}$ arising from (20) is

$$\theta_{i,max} = \frac{w_F}{B_R}. \tag{21}$$

The angle θ_i must satisfy the requirement $\theta_i \leq \theta_{i,max}$.

4. Coupling Efficiency of the FPR

In order to get the coupling efficiency of the FPR we used the analytical Near-Field Method proposed by Kataoka [9]. According to Kataoka, the overlap integral describes the coupling efficiency between the light at the receiving plane of the fiber and the SM (Single Mode) optical fiber

$$\eta = \frac{\left|\int \psi_L(r)\psi_F^*(r)dr\right|^2}{\int |\,\psi_L(r)\,|^2\,dr \int |\,\psi_F(r)\,|^2\,dr} \tag{22}$$

where ψ_L is field amplitude of the incident light at the receiving plane of the fiber, ψ_F is field amplitude of the optical fiber mode inside the fiber and r is radial distance from the optical axis of the fiber. The receiving optical fiber field amplitude (Fig. 4) at the input plane is

$$\psi_F = \sqrt{\frac{2}{\pi}}\frac{1}{w_F}\exp\left(-\frac{r^2}{w_F^2}\right) \tag{23}$$

where w_F is mode field radius of the fiber. We assume that the incident beam, at the plane perpendicular to the axis of the fiber, is circularly symmetric in terms of the radial coordinate r.

Then the field amplitude at the input plane of the receiving optical fiber can be approximated by the Gaussian distribution with radius w_L

$$\psi_L = \sqrt{\frac{2}{\pi w_L^2}}\exp\left(-\frac{r^2}{w_L^2}\right). \tag{24}$$

Transformation of the beam propagating through the receiving optical system is characterized by a complex beam parameter and ABCD law [7]. The complex beam parameter q is defined as

$$\frac{1}{q(z)} = \frac{1}{R(z)} - j\frac{\lambda}{\pi w^2(z)} \tag{25}$$

where R is radius of curvature, w is beam radius at the waist and z is propagation distance.

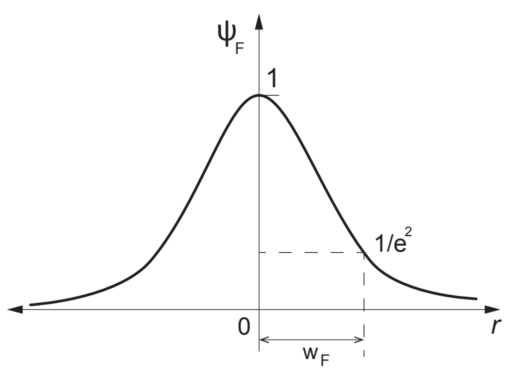

Fig. 4. Mode field amplitude distribution of the single mode fiber.

The complex parameter of the beam q_2 at the input plane of the receiving optical fiber can be calculated by the transformation of the complex parameter of the beam q_1 which enters the receiving Schmidt-Cassegrain telescope. Therefore, the q_2 parameter of the beam at the input of the receiving fiber can be deduced from the ABCD law as follows

$$q_2 = \frac{Aq_1 + B}{Cq_1 + D}. \quad (26)$$

The beam radius and curvature radius of the beam at the input plane of the receiving fiber is calculated by parameter q_2 according to (26).

The coupling efficiency η versus lateral displacement Δ_x of the fiber out of the optical axis, defocus Δ_z and angle deviation ω of the fiber axis from the receiver optical axis is defined as [9]

$$\eta = \eta(\Delta_x, \Delta_z)\,\eta(\omega), \quad (27)$$

$$\eta(\Delta_x, \Delta_z) = \frac{4}{\left(\frac{w_F}{w_L} + \frac{w_L}{w_F}\right)^2 + \frac{\lambda^2 \Delta_z^2}{\pi^2 w_F^2 w_L^2}} \exp\left(-\frac{4\Delta_x^2}{w_F^2 + w_L^2}\right), \quad (28)$$

$$\eta(\omega) = \exp\left(-\frac{2\pi^2}{\lambda^2} \frac{\omega^2 w_F^2 w_L^2}{\left(w_F^2 + w_L^2\right)}\right). \quad (29)$$

The relation between FPR coupling efficiency and FPR coupling loss can be defined by the expression

$$\alpha_{CL} = 10 \log \frac{1}{\eta} \quad (30)$$

where α_{CL} is coupling loss in dB.

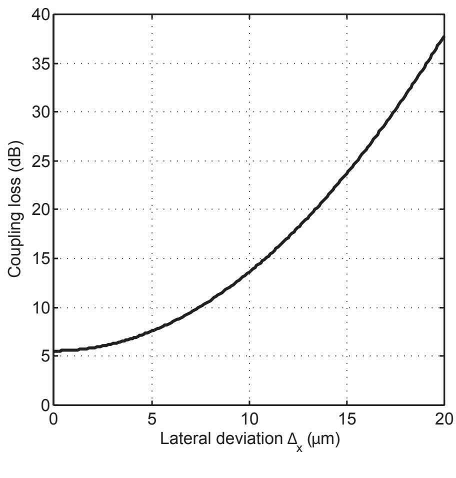

Fig. 5. The coupling loss of FPR as a function of the lateral deviation.

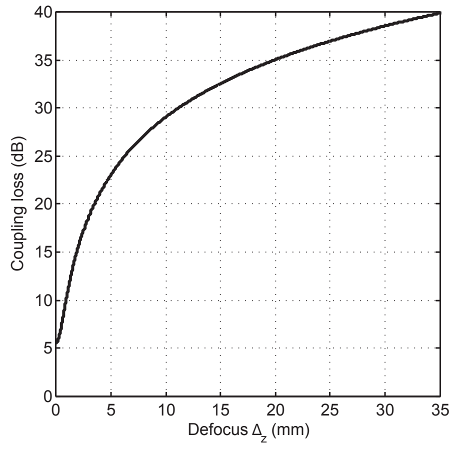

Fig. 6. The coupling loss of FPR as a function of defocus.

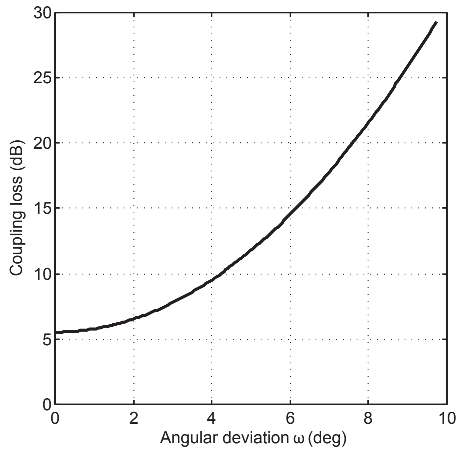

Fig. 7. The coupling loss of FPR as a function of angular deviation.

The FPR coupling efficiency was investigated for singlemode fiber with field radius w_F = 4.5 μm. Once we know the field amplitude distribution of the optical fiber and field amplitude distribution of the incident light at the input plane of the receiving fiber, we can estimate coupling loss from (27)-(30). We obtained the coupling loss 5.2 dB for a perfectly aligned system. To find out how sensitive the system will be to the alignment procedure, the coupling loss as a function of lateral deviation (Fig. 5), angular deviation (Fig. 7) and defocus (Fig. 6) are depicted. The coupling loss α_{CL} is a part of the receiver system loss (see Tab. 1). According to these figures it is clear that alignment of the system is quite challenging.

5. Channel Characterization

A schematic concept of the fully photonic link is shown in Fig. 8. The input optical signal with wavelength 1550 nm is boosted in EDFA. The amplified signal (100 mW) is then led by single mode optical fiber to the transmitter, where it irradiates the transmitting lens. The optical Gaussian beam emanating from the transmitter (D_{TXA} = 25.4 mm) has divergence θ = 1 mrad. After propagation through the free space

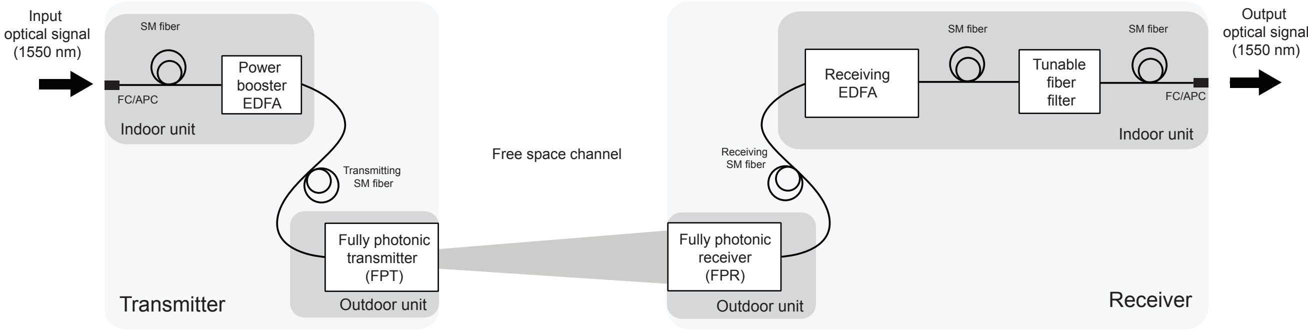

Fig. 8. Concept of the fully photonic link.

channel, the beam is received by the Schmidt-Cassegrain telescope (primary mirror diameter $D_{1,\mathrm{RXA}} = 125$ mm, secondary mirror diameter $D_{2,\mathrm{RXA}} = 50$ mm). The amount of the received power can be calculated as follows

$$P_{\mathrm{RXA}} = \left[\int_0^{\frac{D_{1,\mathrm{RXA}}}{2}} I_0 \exp\left[-2\left(\frac{r}{w_{\mathrm{RXA}}}\right)\right] 2\pi r \,\mathrm{d}r \right] - I_0 \pi \frac{{D_{2,\mathrm{RXA}}}^2}{4} \tag{31}$$

where w_{RXA} is half beam width at the plane of the receiving aperture; r is perpendicular distance from the optical axis of the receiver and I_0 is optical intensity on the optical axis at the plane of the receiving aperture.

The signal received by the Schmidt-Cassegrain telescope is then amplified by EDFA and filtered by a tunable fiber filter. The filtered optical signal is then distributed where it is needed.

Example of possible energetic balances of the link was calculated in a special program which takes into account the statistical characteristics of the area. The results are shown in Tab. 1.

One of the effects caused by atmospheric turbulences, which have an essential impact on availability of the fully photonic link, is fluctuations of the angle of arrival. The incident angle is defined as the angle between the direction of propagation of an optical wave which is incident to the plane of the receiving aperture and optical axis of the receiver [10]. Fluctuations of angle of arrival have direct impact on coupling efficiency of a fully photonic link. As a consequence of angle of arrival fluctuation, the focused optical wave is shifted from the optical axis (image jitter) in the focal plane of the telescope. Due to this shift, the coupling loss increases.

The magnitude of angle of arrival fluctuation depends on the strength of the atmospheric turbulence. The strength of atmospheric turbulence is characterized by the refractive index structure parameter C_n^2. In the area of operation we expected values of the C_n^2 parameter between 10^{-13} m$^{-2/3}$ and 10^{-14} m$^{-2/3}$. It is assumed that the receiver will be placed at the far field; therefore we used relations for a spherical wave.

According to Churnside it is possible to estimate variance of the angle of arrival for a spherical wave [11]

$$\beta_a = \sqrt{\frac{3}{8} 2.91 C_n^2 L D_{\mathrm{RXA}}^{-\frac{1}{3}}} \tag{32}$$

where L is distance between the transmitter and the receiver and D_{RXA} is diameter of the receiving aperture.

After substituting of the link parameters (Tab. 1) to the relation (32) we obtain variance of the angle of arrival approximately 8 μrad. Fluctuations of the angle of arrival in the focus plane of the telescope create an offset of the focus sometimes called "image jitter" or "image dancing". Owing to image jitter, the direction of propagation of light is changed at the input plane of the receiving fiber which causes coupling loss (α_{CL}).

Transmitted optical power (mean)	$P_{\mathrm{m,TXA}}$	19.5	dBm
Beam divergence	θ	1	mrad
Link distance	L	850	m
Wavelength	λ	1550	nm
Transmitter system loss	$\alpha_{\mathrm{trans,\ syst}}$	5.5	dB
Atmospheric loss	α_{atm}	1	dB
Propagation loss	α_{prop}	37	dB
Diameter of receiving antenna (the primary mirror)	$D_{1,\mathrm{RXA}}$	125	mm
Diameter of receiving antenna (the secondary mirror)	$D_{1,\mathrm{RXA}}$	50	mm
Equivalent diameter of the (receiving antenna)	$D_{\mathrm{Eq,\ RXA}}$	114	mm
Total gain of the receiver	γ_{total}	17	dB
Received power	P_{RXA}	-7	dBm
Receiver system loss	$\alpha_{\mathrm{rec,\ syst}}$	15.5	dB
Receiver sensitivity (mean)	$P_{0,\mathrm{RXA}}$	-38	dBm
Margin of the link	M	15.5	dB

Tab. 1. Link budget.

The "image jitter" can be calculated as the root mean square angle of arrival multiplied by the focal length of the receiving telescope [12]. However, we have to take into account the whole receiving optical system including the collimating aspheric lens and GRIN lens. For this, we used relation (20) for estimating of the image displacement at the input plane of the receiving fiber. The value of image jitter is approximately 5 μm. From this value one can estimate the additional coupling loss caused by the angle of arrival from Fig. 5. The loss is about 2 dB. For this particular application of the fully photonic link, the loss caused by the angle of arrival fluctuations is fully acceptable (see link margin in Tab. 1).

6. Conclusions

The paper is focused on modeling and designing a fully photonic link which is used primarily for transmitting highly stable optical frequency – transmission of time. The fully photonic concept of the link brings a number of benefits which improve qualitative parameters of the link: creation of an optimal intensity profile of the transmitting beam, usage of photonic devices such as WDM, EDFA, etc. A fully photonic transceiver only uses passive optical components without any electronic and optoelectronic devices. Lasers, photodiodes, fiber amplifiers and supply blocks are used in the indoor unit which is not so strongly affected by atmospheric changes as the outdoor unit is. An extremely wide band can be achieved by excluding the blocks performing E/O conversion from the communication channel.

However, transmission of highly stable optical frequency with a fully photonic link requires good knowledge of the conditions under which the link will be working. These include statistical parameters of the atmosphere like time dispersion and the effect of random attenuation and turbulence.

The received power by the fully photonic receiver is highly dependent on the fluctuation of the angle of the incident optical wave. Therefore, the paper pays attention to this problem. The authors of the paper estimate the angle of arrival variance caused by atmospheric turbulences. From theoretical prediction, it was assumed that the loss caused by the angle of arrival variance does not exceed the margin of the particular link.

The experiment of the link for transmitting of highly stable optical frequency will be realized in Brno (the Czech Republic) through a distance of 850 m. The optical beam will be propagated above the Technology Park between the Faculty of Electrical Engineering and Communications, Brno University of Technology (FEEC, BUT) and the Institute of Scientific Instruments of the Czech Academy of Sciences (ISI CAS).

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