Preferrulized Cables for Blowing to Homes through 4/3 mm Microducts

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Abstract

An expensive part of installation of FttH networks is connectorization of the cables, especially at the side of the homes. A preconnectorization solution is presented in this paper with preferrulized (LC standard compatible) cables blown from a central point through 4/3 mm microducts to the different homes. At the moment of finishing the home connection the rest of the connector is easily snapped on. This saves difficult (costs) labor at home, even eliminating a home visit, as well as inconvenience for the customers. The performance of the preconnectorization solution is described in this paper with reference to tests in Delfzijl, Netherlands and a 400 homes pilot project in Aneby, Sweden.

Keywords: Optical fiber cable; microduct cable; microduct; fiber to the home; FttH; connector; preconnectorized; preferrulized; blowing; jetting.

1. Introduction

An expensive part of installation of FttH networks is connectorization of the cables, especially at the side of the homes. Preconnectorization is a possible solution, but existing solutions have also drawbacks: Installation of complete cabletrees with preconnectorized connections [1] is difficult to plan and install, blowing of preconnectorized cables in microducts from individual homes [2] is labor intensive and is inconvenient for the customers, and premounted connectors with fiber stub, to be spliced by fusion [3] or mechanically, still requires relatively difficult labor at homes.

As a solution to above mentioned drawbacks preferrulized cables (cables with prefabricated semi-finished connectors, see Fig.1) are blown from a central point through 4/3 mm microducts to the different homes. This reduces labour costs significantly. The cable stops automatically (because of an air-venting end-stop) when the termination points in the homes are reached. There is no need to enter the homes at this part of the installation, a significant advantage. At the moment that a home connection is finished the rest of the connector is easily snapped on. Summarising the advantages:

- Versatility of a microduct system [4].
- No need to detailed plan (branches, cable lengths) in advance.
- Low costs for blowing (or pushing).
- Low costs for mounting home connector.
- Wall box or frame for splicing connector to cable can be eliminated (reduced in size when integrated with electronics).
- Homes need only be entered once.
- No inconvenience for the customers.

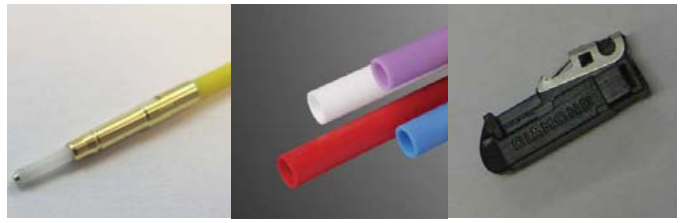

Figure 1. Preferrulized cable (left), microducts (middle) and snap-on connector housing (right), all same scale

Tests with a prototype of the preferrulized (LC standard compatible) cable were first done in Delfzijl, The Netherlands. Here blowing into a 4/3 mm microduct was possible over a length of 1000 m. Currently a pilot project in Aneby, Sweden, connecting 400 homes, is running. The first phase, 61 homes, has been completed. In the second phase also bend insensitive fibers [5] will be used.

2. Blowable Semi-Connector

Specially developed for the blowing technique the connector is a very compact and sturdy Small Form Factor (SFF) ferrule holder which can be blown or pushed through 4/3 mm microducts and can then be finished in the field by a non-expert within a few minutes as an LC compliant (1.25 mm ferrule) connector, which makes it very practical for FttH installations.

2.1 Active Core Alignment

Besides, this connector benefits from the active core alignment technique optimizing the connections' optical performance by positioning the fiber core at the exact centre of the ferrule [6,7].

In fact eccentricities related to the manufacture of optical fiber and ferrules as well as connector assembly can induce lateral alignment errors affecting performance of optical interfaces.

For connectors using full ceramic ferrules manufacturers must select the best ferrule quality and position the ferrule's eccentricity in a predefined quadrant of the connector (tuning technique) in order to reduce fiber core offset between connected ferrules. This process can be critical and time-consuming.

Connectors benefiting from the core alignment technique use a composite ferrule (ceramic and metal alloy). Once mounted the connector's eccentricity is accurately monitored by means of visible light. Knowing the exact position and value of the connector's eccentricity the entire fiber end is moved by deforming the surrounding metal alloy insert with a slight radial displacement. This process enables to optimize the connector's fiber core position with eccentricity values of 0.5 μm or less.

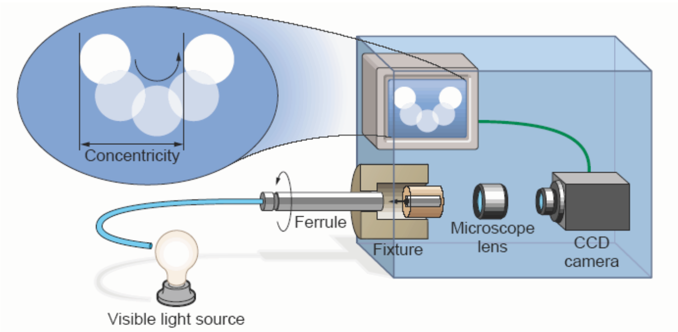

Figure 2. Schematic view of active core alignment

Installing high performance connections like this blowable connector on the side of the homes today represents a long-term investment which will avoid part of future FttH upgrades when higher bit rates are required.

In this paper the results obtained with preferrulized cables containing standard G652 D fibers and Single Mode PC connectors, as used in the first phase of the pilot in Sweden, are reported. During the conference the results from the second phase of the pilot, with bend-insensitive fibers (G657 A+B) [5] are presented.

2.2 Optical Measurements

The finished connectors (Single Mode, PC) show insertion loss of typically 0.25 dB and maximum 0.5 dB and return loss of minimum 45 dB.

Further mechanical and environmental tests will be carried out according to IEC 61753-1 (Category U : Uncontrolled Environment) and will be presented at the conference.

A non standard requirement for this connector is the rapid-stop test as might occur at the end of the pushing and/or blowing operation. For this the preferrulized cable must be able to withstand a pushing force of minimum 50 N.

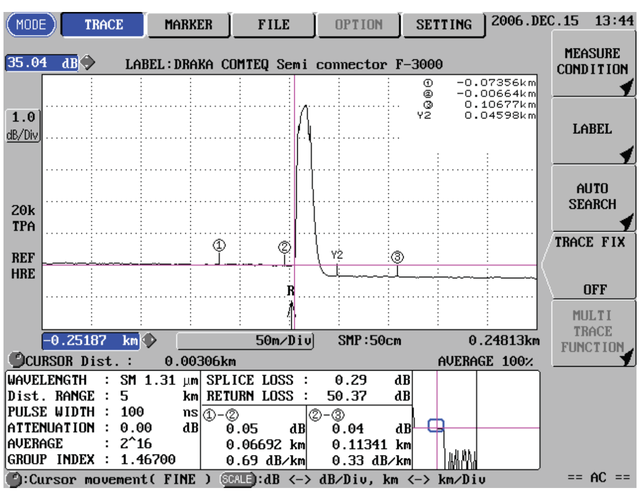

Figure 3. OTDR screendump after preferrulized cable suffered a rapid (hard) stop

The OTDR screendump of Fig. 3 was taken after the preferrulized cable suffered a rapid (hard) stop from a speed of 200 m/min with a pushing machine at only 5 m from the end of the microduct.

2.3 Connector Size and Bend Radius Microduct

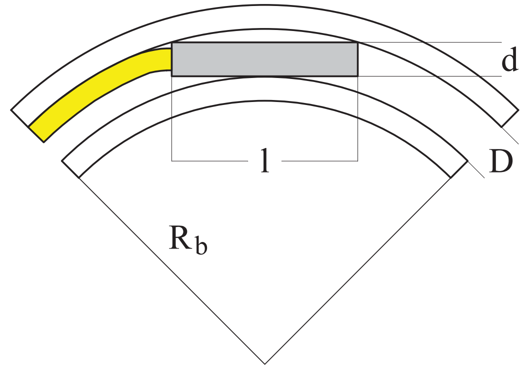

Figure 4. Schematic view of a preferrulized cable in a section of bent microduct

When a preferrulized cable passes a section of bent microduct with inner diameter D the bend radius of the latter cannot drop below a certain minimum value R_b depending on the length l and diameter d of the ferrule:

$$R_b = \frac{\left(\frac{1}{2}l\right)^2 + (D-d)^2}{2(D-d)} \tag{1}$$

From this it follows that the ferrule, which has a size of 22 mm long and 2.2 mm diameter (including metal holder) cannot pass bends in 4/3 mm microducts with bend radius smaller than 75 mm. For 5/3.5 and 5/4 mm microducts this is 50 and 35 mm, respectively. Further in this paper a way is described to pass bends with a radius smaller than what follows from equation 1.

3. Tests Delfzijl

Figure 5. Blowing the preferrulized cable into a 4/3 mm microduct using blowing and lubricator unit

Tests with prototypes of the preferrulized (1.25 mm) cable were first done in Delfzijl, see Fig. 5, 6 and 7. Blowing was possible with 10 bar in a 4/3 mm microduct in a standard IEC 60794-5-10 [8] trajectory of 1000 m long and 180° bends with bend radius of 160 mm every 100 m and a Y-branching duct-connector close to the termination box. There was no loss in performance when compared to blowing without ferrule. At the end of the trajectory a piece of microduct of defined length, with air-venting and end-stop, was placed and the cable came to a full stop automatically when the cable reached the end-stop. The defined length was chosen such that the finished connectorized cable matches the length needed in (or to) the termination box. Inserting the preferrulized cable in the connector housing was done using a special toolset, without any problems.

Figure 6. End of the IEC trajectory with Y-connector and termination box

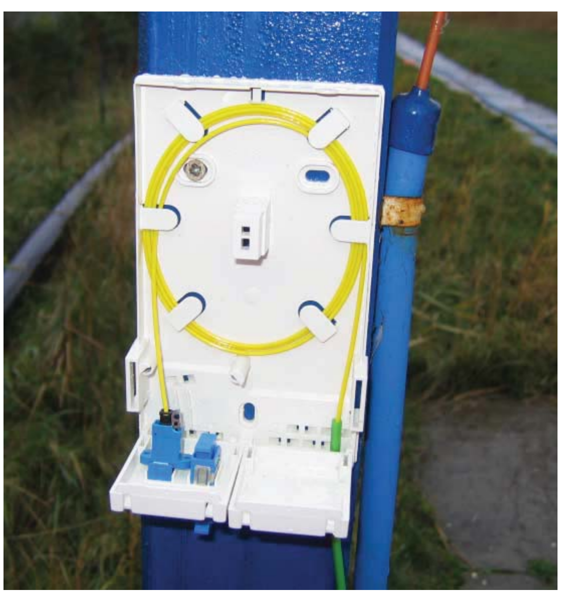

Figure 7. Close up termination box like in Fig. 6

Figure 8. Installation from box with pushing machine on battery-powered drilling machine

Installation tests were also done with a pushing machine mounted on a battery-powered drilling machine (Fig. 8), without using air. Here the preferrulized cable was installed from a box (see further in this paper). When using the proper lubrication a length of 40 m could be installed, with several bends in the trajectory. This length is enough for installation within a single home, but not enough to reach all homes in a typical home-block situation as in the pilot described below (where airflow assists the installation).

Recently a new pushing machine, see Fig. 9, for mounting on a battery-powered drilling machine has been developed [9]. Here different inserts can easily be clipped on, like special high-precision clutches, blowing heads and lubricator units.

Figure 9. New pushing machine for battery-powered drilling machine, with clip-on inserts like blowing heads. The latter is mounted on this picture

4. Pilot Aneby

Currently a 400 homes pilot project with the preferrulized cables is running in Aneby, Sweden, a small community (population around 2000) in Småland, a province blessed with forests and lakes. In the first phase of the project 61 homes, located in blocks of about 10 homes each, see e.g. Fig. 10, were connected. Installation was done from a room in the cellar to all the homes in a block, and sometimes also to another block. The prefabricated lengths selected for the pilot were 50 m, 75 m and 130 m.

Figure 10. One of the blocks of homes of the Aneby pilot

Figure 11. Blowing from a box

Installation of the preferrulized cables from different small spools and boxes was tried. In the latter case the cable is stored in loops with torsion, freed again during pay-off. The loops coming out of the box, see Fig. 11, needed guiding by hand. The cable suffered too much from memory after being stored in the box for a long time (this was not the case with the cables tested in Delfzijl, which were made with a different cable jacket material). The boxes could still be installed, but will be abandoned for the rest of the pilot. Experiences with big and small spools, the latter see Fig. 12, were positive. The small spools will be used in the rest of the pilot.

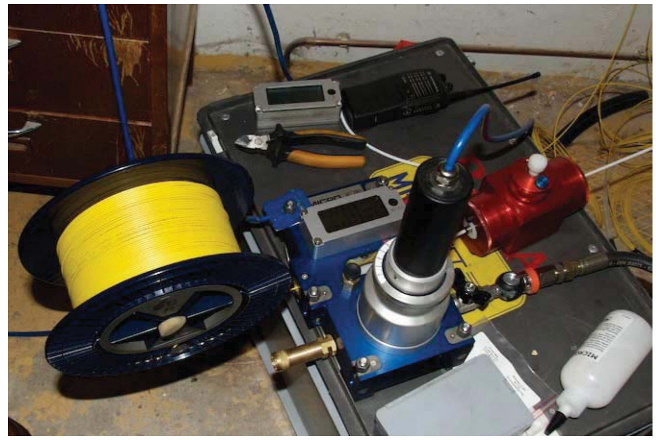

Figure 12. Blowing from a small spool

4.1 Small Bends

Blowing through most bends in the microducting attached to the wall was possible, e.g. the ones shown in Fig. 13. The existing wall boxes, however, see e.g. Fig. 14, could not always be passed. The smallest bend radius seen was 35 mm. The preferrulized cable has been developed for a minimum bend radius of 75 mm (this is 35 mm for 5/4 mm microducts). During the first cables blown the microducts were opened temporary at the wall box locations. The rest of the cables were blown with the microducts extended and hanging out of the wall boxes during installation, see Fig. 15. After the cables passed the microducts the loops were placed back inside the wall boxes again.

Below in this paper other solutions to pass the small bends are tested (in Delfzijl). They will hopefully be implemented in a later phase of the pilot.

Figure 13. Bends in the bundles of 4/3 mm microducts, 12 of them in a black flame retardant flexible duct

Figure 14. Existing wall boxes with lack of space and microduct bend radius of 35 mm

Figure 15. Existing wall boxes with extended microducts, hanging out temporarily

To overcome the problems mentioned above two solutions were tried (in Delfzijl, after the first phase of the pilot):

1) Placing a piece of microduct of higher diameter at critical locations, see Fig. 16, where a piece of 5/3.5 mm microduct is placed in between the 4/3 mm microduct sections. In principle all kind of higher diameter cable guiding channels can be used for this purpose, e.g. any shape of preformed components to pass sharp bends at house walls.
2) Using an air suction pig attached to the pre-ferrulized cable's end, see Fig. 17, where a plastic suction pig is attached to the ferrule's end protection-cap (not shown in Fig. 17).

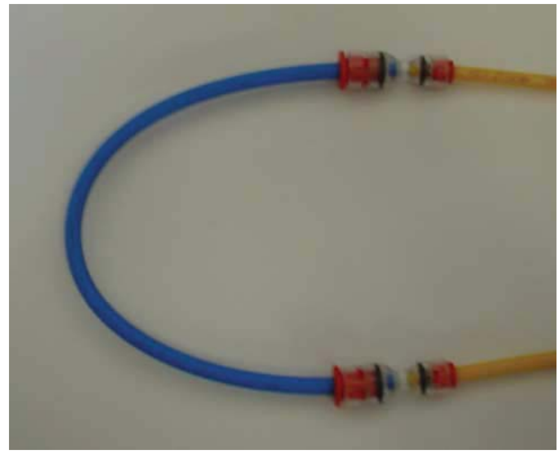

Figure 16. Bend of 5/3.5 mm microduct placed in between 4/3 mm microduct sections

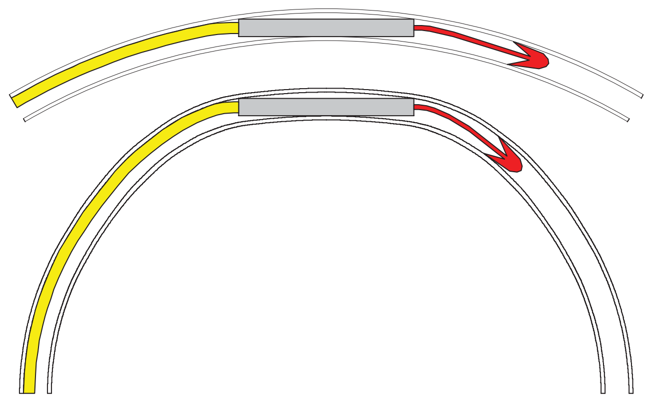

Figure 17. Schematic view of a pre-ferrulized cable with attached air-suction pig. Above the curvature that can be passed according to equation 1. Below a much sharper bend is passed when the air suction pig pulls the pre-ferrulized cable through the bent microduct while deforming it locally

For the test 100 m of 4/3 mm microduct was laid on the ground in loops of 10 m with after each loop 180° bends of 20 cm bend radius. Halfway, at 50 m, a sharper bend was made with the microduct in a bench vice, where the bend radius (twice the plate-distance inside the bench vice; in fact the bend radius in 2-point bending is a little less than half the plate distance) could be varied. The pre-ferrulized cable was blown in with 10 bar.

First tested was just the bare cable with a short conical end-cap through the bent 4/3 mm microduct. Here the cable passed a minimum bend radius of 35 mm, without a dip in the speed and reaching the end of the microduct with the speed unchanged at 46 m/min.

Second test was with the pre-ferrulized cable through the same bent 4/3 mm microduct. Here the minimum bend radius that could be passed was 75 mm, with the same unchanged speed. This result matches theory (equation 1).

Third test was with the pre-ferrulized cable through the bent 5/3.5 mm microduct placed in between the 4/3 mm microduct sections, see Fig. 16. Here the minimum bend radius reached was 55 mm, slightly larger than predicted in theory (equation 1), probably due to the relatively high stiffness of the 5/3.5 mm microduct.

Fourth test was with the pre-ferrulized cable again through the bent 4/3 mm microduct, but now with a suction head attached to the end-cap on the ferrule. No professional suction pig of the right size was yet available for the test, so a foam-plug was improvised, attached to the end protection-cap on the ferrule using a piece of aramide yarn. The foam plug, which can pull up to 7 N when 10 bar air pressure is used, forces the pre-ferrulized cable through the bent microduct, while temporarily deforming it locally, see Fig. 17. The smallest bend radius reached without drop in speed was 40 mm. At a bend radius of 35 mm the ferrule was first blocking but, after the pressure behind the foam plug was built-up again a few seconds later, started again and reached the end at full speed. Note that, due to the difficulty to pull back the foam plug every time a smaller bend radius was tried, the sharp bend was moved to 80 m for the last trial at 35 mm bend radius.

4.2 Mounting the Connector

When the preferrulized cable is blown until the end of the piece of microduct of defined length (with air-venting and end-stop), placed at the home termination, this piece is removed. Next the cable boot and a metal cylinder are sleeved over the ferrule holder. Then the metal cylinder is crimped around the ferrule holder and the cable jacket using a crimp tool, see Fig. 18, for extra strength. Now the ferrule holder is pushed into the connector housing, the latter being placed in a special holder, see Fig. 19. Finally the cable boot is pushed over the metal cylinder. In Fig. 20 the finished connector is shown.

Figure 18. Crimping cylinder around ferrule holder

In Fig. 20 also the frame is shown on which the electronics will be placed. Inside the frame, which was formerly used to store the splice to the pigtail with SC-connector, there is place for patching from the LC compliant connector to an SC compliant connector. In the future electronics with LC compliant sockets will be used and the whole frame is not needed anymore.

Figure 19. Pushing ferrule holder into connector housing

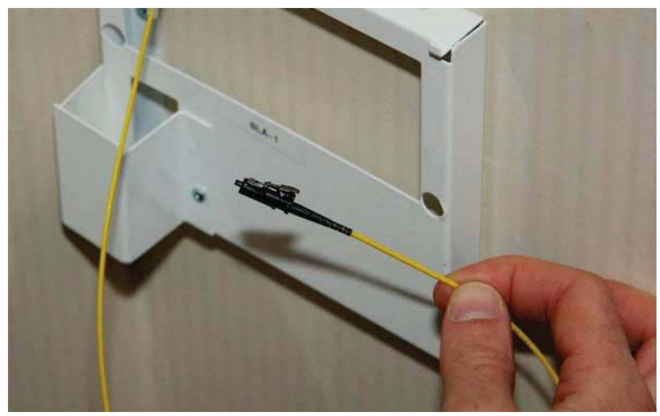

Figure 20. Finished connector

4.3 Time to Install

The first part of the pilot (cable installation) started on Monday, May 7th at 9:30 am. First some instruction was given to mount the connector. At 5:15 pm the cables were blown to 19 homes of which 5 were finished with the connector (the ”connector man” was needed on another project during the afternoon and returned the other day, late afternoon). After the learning curve of Monday the remaining 42 cables were blown in on Tuesday. The connectors were finished on Wednesday 9:00 am.

5. Conclusions

Preferrulized cables have shown to be an economic solution for installing FttH networks. Difficult labour at the customer’s homes is eliminated, as well as an extra home visit. The connecors show superior optical properties, due to the technique of active core alignment. Blowing of the preferrulized cables through narrow 4/3 mm microducts is possible over more than 1000 m. In Aneby, Sweden, a pilot (400 homes) is running of which the first phase (61 homes) was completed in 2 days, the cable blowing including finishing the connector. Existing wall boxes, where a smallest bend radius of 35 mm was found for the microducts, could not always be passed. This was solved in the pilot by extending the microducts there and hang them out of the boxes temporarily. In Delfzijl another solution was found by attaching an air-tight suction pig to the pre-ferrulized cable, making it possible to pass the 35 mm bends.

6. Acknowledgments
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8. Biographies

Willem Griffioen received an M.Sc. degree in Physics and Mathematics from Leiden University (Netherlands) in 1980 and worked there until 1984. Then he joined KPN Research, Leidschendam (Netherlands). Responsibilities R&D of Outside-Plant and Installation Techniques. He worked at Ericsson Cables, Hudiksvall (Sweden) and at Telia Research, Haninge (Sweden) in the scope of exchange / joint projects with KPN Research. He received his Ph.D. (Reliability of Optical Fibers) in 1995 from the Technical University of Eindhoven (Netherlands). Currently, since 1998, he is product manager at Draka Comteq Telecom, Zuidelijk Halfrond 11, 2801 DD Gouda, The Netherlands.

Willem Greven received his degree in advanced technical studies in Delfzijl in 1977. Since then he jointed Draka Comteq - NKF Telecom, IJzerweg 2, 9936 BM Farmsum (Netherlands). He worked at departments of paper-insulated cables, plastics, was quality inspector, co-ordinator final inspection and unit-leader plastics. Since 1996 he joined the team that develops and introduces the JETnet system as senior projects & systems engineer. He made demonstrations and pilot projects of the system all over the world.

Thomas Pothof joined Draka Comteq - NKF Telecom, IJzerweg 2, 9936 BM Farmsum (Netherlands) in October 1968. He started at the department of paper-insulated cables. Then he worked for some years as quality inspector in the plastics department. Next he was one of the pioneers in the optical cable department, in the function of group leader. After introduction of self-steering teams he became materials planner of this department. In October 2000 he joined the JETnet team as projects & systems engineer.

Ivar Koren worked form 1991 to 1999 as a measurement specialist in the OSP. In 2000 he worked at a Optical Training department from KPN and Dirksen Opleiding as a trainer for optical fibre management systems. In April 2005 he joined Diamond Kimberlit BV, Transistorstraat 101, NL-1322 CL Almere (Netherlands) where he started at the product management department as productmanager for optical interfaces.

Didier Colot is graduated from the HEC Business School of Liège (Belgium) as a Commercial Engineer. After working in Belgium, Luxemburg and Italy in the IT sector as a Project Manager, Consultant and Sales Manager for different international firms he joined DIAMOND beginning 2006. After a few months long mission at DIAMOND’s subsidiary in The Netherlands he came back to DIAMOND Headquarters in Losone (Switzerland) where he is currently Responsible for the International Sales Department.

Victor Coggi received his degree in mechanical engineering at the Institute of Technology (ETH) of Zurich (Switzerland). In 1999 he joined DIAMOND with the initial function of Product Manager with responsibility over the all fiber optic connector program. Since 2003 he is director of the technical department at DIAMOND Headquarters in Losone (Switzerland) in charge of management of R&D activities for fiber optic components and related equipment.

Magnus Eriksson, received his degree in technical studies in Halmstad in 1983. Since then he joined the Swedish Telphone company - Televerket. He worked during the eighties with outside plant projects. Since 1990 he starts to works with designing access networks. The last 3 years at TeliaSonera (former Televerket) he worked with tenders and technical specifications for the contractors. From 2003 he started at RaLa InfraTech AB and is working to sell fiber solutions to customers - JETnet solutions.

Tobias Ahl joined RaLa InfraTech AB, Skänninge, Sweden, in January 2000. He started as product manager for micro cabling systems and installations technology. Focus is FTTH and urban network. Since 2005 he is the managing director of RaLa InfraTech AB. He received a M.Sc. degree in Applied Physics and Electrical Engineering from Linköping University (Sweden) in 1998.

Karin Gustavsson, within RaLa is in charge of local metro nets within Sweden. Karin got her Master degree in Social and Political Science during 2001 and ever since that she has been working as a consultant within the metro nets. Karin also has an experience from participating in the Svenska Stadsnätsföreningen as member of the projekmanagergroup. Karin has been a part of RaLa since 2005.